SUPPLEMENT

TO THE

# JOURNAL OF GAS LIGHTING,

## WATER SUPPLY, & SANITARY IMPROVEMENT.

VOL. XVI. LONDON, JULY 9, 1867. No. 384.

## BRITISH ASSOCIATION OF GAS MANAGERS.

THE Fourth Annual General Meeting of the Members of this Association was held at the School of Art, Waverley Street, Nottingham, on the 11th, 12th, and 13th of June.

The following is the list of gentlemen present on the occasion :—

MEMBERS.

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| W. Eason, Cheltenham. | Dr. Letheby, London. |
| W. Fiddes, Bristol. | C. Hawksley, London. |
| E. Goddard, Ipswich. | A. Milne, Louth. |
| E. S. Cathels, Sydenham. | T. H. Bouttell, Sleaford. |
| J. Blackburn, Droylsden. | J. Barras, Rotherham. |
| J. Wood, Bury. | J. Arnott, Leeds. |
| W. J. Warner, South Shields. | T. H. Methven, Bury St. Edmund's. |
| J. T. Hall, Liverpool. | J. T. B. Porter, Lincoln. |
| D. Webster, Southport. | J. Miles, Tyldesley. |
| T. Hawksley, London. | W. Miles, Clitheroe. |
| P. Simpson, Rugby. | C. Woodall, Stockton. |
| A. C. Fraser, Colchester. | E. H. Harris, Wallasey. |
| M. H. Loam, Nottingham. | D. Brandwood, Radcliffe. |
| A. Owst-Atkinson, Hull. | H. G. Crowe, Wellington. |
| J. Booth, junr., Stalybridge. | W. W. Hutchinson, Barnsley. |
| W. J. Moon, Malton. | A. Young, Stoke-upon-Trent. |
| J. Eldridge, Richmond. | C. Taylor, Derby. |
| W. Longworth, Dukinfield. | J. Somerville, Maidstone. |
| W. Smith, junr., Hyde. | J. Brown, Waltham Cross. |
| J. Hutchinson, Barnsley. | W. Stout, Boston. |
| W. H. Willis, Great Yarmouth. | T. Bell, Selby. |
| W. Wood, Farsley. | R. H. Jones, Dover. |
| T. Bull, Tamworth. | G. Anderson, London. |
| W. H. Chambers, Lowestoft. | J. Cockcroft, Littleborough. |
| J. Martin, Ormskirk. | J. Paterson, Warrington. |
| T. Rafferty, Manchester. | W. Shimeld, Dundalk. |
| J. Ohren, Longton. | J. Russell, Uxbridge. |
| John Storer, Stafford. | W. R. Cooper, Banbury. |
| W. P. Throsby, Lincoln. | J. Annan, Wolverhampton. |
| T. Andrews, Swansea. | C. Dixon, Chichester. |
| O. Brothers, junr., Blackburn. | H. P. Stephenson, London. |
| S. B. Darwin, Shrewsbury. | R. Douglas, Newcastle-on-Tyne. |
| E. White, Birmingham. | J. Douglas, Portsea. |
| G. J. Parkinson, Birmingham. | J. Davies, Kidsgrove. |
| G. B. Irons, Gosport. | J. Dunning, Middlesborough. |
| G. A. Allan, Willington Quay. | H. Cockey, Frome. |
| M. Broadhead, Great Grimsby. | T. Dand, Exeter. |
| G. T. Livesey, London. | A. Potter, Willington Quay. |
| T. Newbigging, Bacup. | H. Woodall, Longport. |
| P. J. Wates, Loughborough. | J. Deakes, Worcester. |
| &c., &c. | |

VISITORS.

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| Alderman R. Rumney, Manchester. | H. Warsop, Nottingham. |
| W. Sugg, London. | E. A. Loam, Nottingham. |
| F. W. Hartley, London. | S. Tagg, Radford. |
| J. Wilson, Nottingham. | H. E. Wharton, Basford. |
| J. Weeks, Nottingham. | &c., &c. |

On Tuesday, June 11, the president, THOMAS HAWKSLEY, Esq., took the chair at twelve o'clock.

The HONORARY SECRETARY (Mr. Jas. Blackburn, of Droylsden) read the minutes of the last meeting, which were confirmed.

The financial statement of the committee, having been previously circulated among the members, was taken as read.

The following gentlemen were candidates for membership in the Association :—

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| C. Dixon, Chichester. | W. Bates, Worksop. |
| J. Davies, Kidsgrove. | J. Cockroft, Littleborough. |
| A. E. Baron, King's Lynn. | W. Brown, Stretford, near Manchester. |
| J. Deakes, Worcester. | T. Trewhitt, West Hartlepool. |
| O. Brothers, junr., Blackburn. | I. Kelsall, Ashton-under-Lyne. |
| E. Brickles, Santiago, Chili. | E. Chattwood, Ramsbottom. |
| J. Niven, Clayton, near Bradford. | W. Lawson, Knottingley. |
| J. Miles, Tyldesley. | A. A. Croll, London. |
| W. Miles, Clitheroe. | J. Burgess, Huddersfield. |
| E. L. Ridgway, Aberdare. | T. Bull, Tamworth. |
| J. Phelps, junr., Marlborough. | T. Stone, Sudbury. |
| H. G. Crowe, Wellington. | E. H. Harris, Wallasey, Birkenhead. |
| J. Donaldson, Dover. | J. T. B. Porter, Lincoln. |
| J. Stevenson, Dublin. | G. W. Stevenson, London. |
| J. W. Thompson, Yeadon, near Leeds. | F. J. Stevens, London. |
| T. H. Bouttell, Sleaford. | J. Arnott, Leeds. |
| W. W. Hutchinson, Barnsley. | J. Russell, Uxbridge. |
| C. Taylor, Derby. | C. Copland, junr, Hull. |
| H. P. Stephenson, London. | S. B. Darwin, Shrewsbury. |

On the motion of Mr. BARRAS, seconded by Mr. WHITE, the list of candidates was approved, and the several gentlemen named were unanimously elected members of the Association.

The PRESIDENT then delivered the following

INAUGURAL ADDRESS.

Gentlemen,—It has hitherto been the custom for your president for the year to deliver what has been called an inaugural address. I am sorry to say that I do not apprehend that I am the best possible person to deliver such an address; but occupying as I do, for the time being, the chair of this association, and having the honour to represent better men of a future period, I shall do my best to place before you so much as I think may be interesting to you of the course of events in relation to gas during the past twelve months.

But first, and as a matter of the highest interest, let me mention to you the progress of the society itself. To my great surprise—for I admit that it is a matter which has far exceeded my anticipations—this society, which was commenced on the smallest possible scale only three years ago, has now taken a place, and I may even say a high place, among the learned societies of this kingdom. Although our objects and purposes are entirely of a special character, and consequently we can never expect to quote numbers equal to those which some societies of a more general character obtain, yet we now number no fewer than 177 members. Those 177 members, devoting their attention to one pursuit, and having in their eye one special object, cannot fail to produce a great development in the science of the subject, and not only in the science of the subject, but in its practical applications also.

Gentlemen, the last year has not been a very eventful one to the gas companies themselves, although they have been greatly affected in their financial position by the unfortunate incidence of the commercial crisis. They have also been seriously affected by the great rise in the price of coals, in the cost of labour, and in the diminution of the value of residual products. All these things have rather conspired to the damping of enterprise in relation to gas undertakings. But still there is some compensation, and that compensation arises in this way, that by the employment of greater skill in the manufacture of gas, the production and distribution of gas has been made more economical than it formerly was. The result, however, of the year's experience has been this, and I believe what I am about to say will be very generally admitted, that although there has been this compensating element introduced, yet that on the whole gas companies are suffering very severely from the operation of the causes I have mentioned. And that brings me, therefore, to this, that it will be the main duty of all of us, as engineers and gas managers, to look hereafter to the economy of the manufacture, and to the improvement of the processes of manufacture, and also to bend our attention to the discovery, if such be possible, of materials from which light may be elicited by means of our undertakings of a cheaper description. Attention has been paid, and a considerable amount of attention, too, in consequence of the increased cost of the articles from which gas has been manufactured, to the means of diminishing the cost of production within the walls of the retort-house. I do not think that very much has yet been accomplished, but arising out of the combinations of workmen, and the consequent great increase in the cost of labour, skill and invention have been applied to discover some method of charging retorts mechanically. Those means, no doubt, have been attained, but the commercial results, so far as at present have been ascertained, are not so satisfactory as it was once thought they would be. However, as a process, and a process which is not at present generally known, it may be mentioned that mechanical appliances have been brought into use by which a large system of retorts, set in one oven, can be all charged at once, by a series of scoops operating at the same instant and discharging their contents into the retorts, so far diminishing the cost of manual labour. Whether this will at all conduce in the end to the economy of manufacture, has not yet been ascertained. Of course a process of that kind is not applicable in small works. It is scarcely applicable in works of moderate size, and is, indeed, only fairly practicable in works of very considerable and almost, I may say, of the greatest magnitude.

Another subject has occupied a great deal of attention, and that is the preliminary processes concerned in the purification of coal gas—that is, the condensation and washing of the gas—and some very important results have now been made apparent; they refer especially to this, that by the use of the alkaline product of the distillation of coal—viz., the ammonia—which every one has at command, not only can a great number of the volatile products, such as the tarry matters and other vapours, be removed from the gas, but also that most obnoxious of all matters, the bisulphide of carbon, can be greatly diminished. Under those circumstances, it may be worth the while of the members of this association, each in his own locality, so far as his own means render it possible, to apply this system, because if

there be one thing more injurious than another to the persons by whom gas is consumed, it is the presence of sulphur in any amount in the gas at the place where it is employed. So strongly am I impressed with this that I have thought it worth while to show you what in bulk is the amount of sulphur in 1000 cubic feet of gas—I mean the minimum quantity to which it is required to be reduced by the various Acts which have recently received the sanction of the Legislature. Now, gentlemen who have not hitherto paid much attention to the subject of the removal of the bisulphide of carbon from gas (for the removal of the sulphuretted hydrogen is a thing which we know how to accomplish, and do accomplish in a satisfactory manner) will be astonished, I have no doubt, when I show them that the quantity of sulphur yet left in 1000 cubic feet of gas, after all has been done to bring the amount of this obnoxious product within the parliamentary standard, is the quantity I now exhibit in this bottle. [The President exhibited a bottle containing a quantity of sulphur.] Now, if you will only imagine, and we are all deeply concerned in this subject as gas managers, that in much of what is called pure gas, as delivered to the public, there is this quantity of sulphur in every 1000 feet, I think we shall all be agreed in the desirableness of adopting some means, if such means can be discovered, for the removal of this obnoxious material.

Permit me, then, to mention to you, merely as a subject for your consideration—for you all know a great deal about it, and many of you much more than myself—that the use of oxide of iron, which is in itself a very valuable material for the ordinary purification of gas from sulphuretted hydrogen, is insufficient, and a great deal of the obloquy which has fallen upon gas companies during the last few years has arisen from the adoption of that material in substitution for the old mode of purification. The old mode of purification is no doubt in many respects an undesirable one and an objectionable one, because it requires that you should bring a large quantity of lime upon the works, which afterwards in most cases it is very difficult to get rid of; and we all know that the lime is very liable to, and in all ordinary cases does give off an obnoxious smell in the neighbourhood. But it undoubtedly has this property, that if it creates a smell by reason of its being kept on the gas-works, it prevents a much more serious smell in the houses of the consumers, for what you fail to take out of the gas by the use of the oxide of iron in substitution of the lime, really goes into the dwelling-houses and manufactories and shops of the consumers in the form in which I exhibit it, combined, of course, with the gas; but still in every 1000 cubic feet of gas there is this large quantity of sulphur to be burned in the interior of the buildings where the gas is distributed.

Under these circumstances, great attention has been paid (and I must thank my friend, Dr. Letheby, for the great assistance he has rendered in the matter) to the elucidation of a better chemistry on this subject, and it has been ascertained by him, as the result of a great number of experiments made upon a very large scale, a considerable portion of which were conducted in this town, that whereas by the use of oxide of iron you cannot remove the whole of the sulphur, but must leave in the gas from 20 to 25 grains in every 100 cubic feet, yet by the use of lime alone you may reduce that quantity down to less than one-half—in fact, you may reduce it down to from 10 to 12 grains.

Then comes the consideration as to whether in gas-works generally we should go back from the present system of using oxide of iron to the use of lime, or whether we should combine both in the process of purification. That, of course, must be left to the decision of every engineer for his own purposes. What might be right to do in one place may be wrong in another. It may be very right, in places where lime can be got rid of without much expense or a great deal of labour, to continue the use of lime, or to return to the use of lime. In other cases, as in the London works, where it is exceedingly difficult to get rid of the lime, and in some of the works in the interior of other large towns, it may be desirable to continue the use of oxide of iron as the first part of the process, and afterwards to remove the bisulphide of carbon and the carbonic acid by passing the gas through vessels charged with lime or other alkaline matters, although at present no alkaline matters are known to be so cheap, so available, and so generally useful as lime. I believe, in a great number of cases, it will be found that it is desirable to adopt that process, but not very desirable to adopt it by combining the two agents in one vessel. The much better way is to have two sets of vessels, the oxide of lime in the first set, and the lime in the second.

This, as a matter of course, raises the question of cost; and here, perhaps, I am going rather out of my way, as your president, in delivering somewhat of a lecture upon the subject; but then comes, as I have said, the question of cost. It has, by careful calculation and observation, been ascertained that the additional cost in that case will amount to about one penny per 1000 cubic feet. That is a very considerable sum, for though it sounds little when stated at one penny per 1000 feet, yet upon the result of a year's working, where many millions of feet of gas are made, it amounts to a very large sum. And that, again, raises the question of what is the duty of a gas company to be, and what are the public willing to pay for? Now, according to my experience, the public are willing to pay for a pure gas, if the subject be properly explained to them; and looking at the action which is now being taken by Parliament in these matters, and how obnoxious gas companies become, and the amount of obloquy that is thrown upon them if they refuse to make improvements, I consider it a fit subject for discussion, if not at this at some future meeting of this association, as to whether it would not be much better that gas companies should submit to an additional cost, and that the public, of course, should be made to reimburse the companies for that additional cost. All these things tend to enhance the price of gas, but the result is that the public get a much better article, and they become very much better satisfied with the companies which deliver to them that improved article. This, gentlemen, is the result of my own information upon the subject, but I admit that it must be dealt with by every member in accordance with his own interests and the interests of the company he represents, and that in this respect each one must do what is right in his own eyes. Still, it is a matter for discussion, for we are all deeply concerned in it, and I hope it will be freely raised, and that we shall all do our best to arrive at some satisfactory conclusion.

The next subject which has been greatly debated in the past year, in a public point of view, is the subject of the distribution of gas, and Parliament is now considering questions connected with the distribution of gas which are of the highest interest to us. But the matter to which I wish principally to draw your attention is the question of leakage, upon which, indeed, we are to have a paper read, which, I hope, will lead to an instructive discussion. It is charged against gas companies that a very large proportion of their gas is lost by leakage. Now I do not believe it. I believe the quantity of gas lost by leakage in a town where the main-pipes are laid reasonably well is very small indeed. It is true that in many places when the ground is opened there is a smell of gas, or gas products in some form or another—probably ammoniacal products chiefly—but it must be borne in mind that the smell arises from very small leakages, which possibly have been going on for forty or fifty years, and that they do not represent any large escape as measured by a per centage of the whole volume of gas passed through the pipes. So far as my own observation teaches me, I believe the greatest quantity of leakage so called arises from service-pipes and not from main-pipes. That there is any escape of gas through the metal of the pipes itself I do not believe. There is no proof of it, and I think such a thing is utterly impossible. But we do know that there is a very large amount of leakage arising from the destruction of the service-pipes. And that will open another subject for consideration, as to whether the time has not come, and whether it is not right and proper and necessary, for some other metal to be used in gas-works instead of the very oxidizable and destructible metal, wrought or malleable iron, which we are now accustomed to use for the purpose. I know that in many cases lead pipe has been used with great advantage, and that in those cases the effects on the amount of loss by leakage have been manifest. I do not say that you should all resort to that means of diminishing the amount of leakage, but it is, at all events, very well worthy your consideration whether wrought-iron tubing is really the best means of carrying the gas from the mains into the houses of the consumers. I wish to be present on the discussion of that subject, and I hope that although we have no paper which presents it to us this year, we shall, on some future occasion, perhaps at our meeting next year, be privileged to have some member of the association bring forward his experience in connexion therewith.

There is also the very important question,—and it is one which I am aware I must touch upon with very great delicacy—viz., the best meter to be employed for measuring gas. I cannot say, as some persons would say, that this is simply a trade question, because if one description of meter—I am not now speaking of one manufacturer as against another—but, if one description of meter be found to register more accurately the quantity of gas delivered to the consumer than another description of meter, in my opinion that description of meter ought to be resorted to. I have myself an opinion upon that subject, but I think every member of this association has the means in his own works of making very valuable experiments with reference to it, and what I would venture to recommend is this, that before our next meeting gentlemen should take indiscriminately from their consumers a number of different classes of meters, connect all these together very carefully, let the same gas through them all, and then record their several indications. I have no doubt that if that course were adopted we should be enabled as the result of a great number of experiments, which may be very discordant among themselves, nevertheless be able to arrive at a very distinct conclusion as to which is the best meter to be used.

Now this, gentlemen, is an important question, because it really touches the question of leakage, inasmuch as the gas companies are charged with leakage for all the gas which cannot be accounted for. My own impression, as the result of a considerable amount of experienced, is that when the leakage is something like 15 or 20 per cent., there is really not so much as 5 per cent. escapes from the mains of the companies, and that the other and much larger portion of the leakage is to be attributed to defective service-pipes, to meters which do not register the whole quantity of gas which passes through them, and to some extent, though not to a very large extent, to fraudulent misuse of the gas. I do not think the fraudulent misuse of gas amounts to one quarter per cent of the quantity passed through the pipes of the companies, although it does to some extent tell upon the total.

But while I am upon this subject, which is one of so much interest, you will probably allow me to mention to you the enormous importance of considering—and it is only for the purpose of asking your consideration of it that I mention it—the best means of supplying gas to the public lamps. Usually the public lamps are supplied with a very much larger quantity of gas than is intended to be delivered. That again becomes an element of "leakage"—an element of that loss which the parties who are opposing the gas companies are always bringing under the notice of Parliament, and for which they are continually charging the companies with bad management, inattention, and ignorance. Now it is singular enough that in this town we have had the means of putting to the test the advantages and disadvantages of supplying the public lamps by average meter indication. As a rule, the attempts which have been made hitherto have been signal failures. In this case it has been as signal a success, and the causes of that success have been these—that every lamp has been governed by a proper self-acting regulator. The regulator that we have generally adopted (but there are several which are equally good) is the one which has been denominated "Sugg's Regulator." That has been found perfectly capable of producing uniformity in the size of the

flame, and our experience has been that by measuring the delivery to one lamp in twelve, we have, as we believe, got a fair indication of the total quantity of gas supplied to the whole. There has been elsewhere a second failure, and one which has brought the matter into contempt, and that is the unmanageability of the meters, and their inaccuracy, which have been used for the purpose of measuring the gas to the lamps. Here we have had a special meter made, and fixed in a special manner, and though this meter did not succeed very well in the first instance, yet, in consequence of alterations which experience has shown to be necessary (chiefly in the dial part, where it might have been thought an alteration would scarcely be needed), it now acts so perfectly that we have no cause to complain at all. I can only say that by the use of this meter we have been enabled to diminish, and in a very notable and important proportion, the quantity of gas which formerly was supposed to be leakage. That is, of course, a great saving to the company, and was formerly a great waste to the town. Both parties are thus benefited, and perfect satisfaction is given; and seeing that is the case, although the question is not without its difficulties, I say that no gentleman need hereafter fear to resort to average meter indication, if he thinks fit to do so, as a means of testing the quantity of gas delivered to the public lamps.

The next subject which has engaged attention during the year, and this year in a way more immediately than heretofore, has been the question of the quality of the gas in respect of its illuminating power. You are all aware that owing to a considerable amount of dissension which took place in London with reference to the legislation of a few years ago, the whole of the metropolitan gas companies, consuming coal to the extent of more than 1 million tons per annum, and making more than 10,000 million cubic feet of gas, have been brought under the cognizance of Parliament by a forced measure. That is a very unusual thing, and is one which represents a position in which we should one and all desire never to be placed. Well, gentlemen, the object of the parties who thus forced this question upon Parliament has been chiefly to get the illuminating power of the gas supplied to the public raised to a higher standard. They have conjoined that with a determination, if possible, to do the other, and the opposite or very reverse thing—namely, to get that increased illuminating power at a reduced price. But the main question after all which we have got to consider is the possibility, in the different places with which we are connected, of getting gas of a quality higher in its illuminating power. Now it is quite true we shall gain a little—at all events in those works in which the gas is purified solely by oxide of iron—by taking out the carbonic acid by the use of lime. That is somewhat of a compensation for the extra expense of purification by that process, but, after all, it is but little. We may gain half a candle by that means, but the object of the promoters of the present agitation is to render it compulsory upon all gas companies in London to supply gas of a minimum illuminating power of 18 candles, the measure of that illuminating power being taken at a distance of 1000 yards from the gas-works. Now we all know that no ordinary coal will give an illuminating power of that quality, and yet we must all feel that whatever is done in London, and other places which are very far removed from the coal-fields, will have to be done, in all probability, in the very places with which we are connected. It therefore becomes a very important question for us to ascertain what we can do within certain reasonable limits of cost.

Now, looking to the greatly enhanced price of coal—looking to the impossibility after many years of obtaining a supply of the quality of the coal that is necessary to give that illuminating power—I think we shall all come to the conclusion that the standard proposed to be fixed in London is, in general, too high, and that it is a standard which cannot be maintained, although it may be attained for a short period, in any places which are not proximate—I might almost say, immediately proximate to the cannel coal. But, gentlemen, as in my inaugural addresses I have usually made recommendations, or rather suggestions as to what we should pay attention to in the coming year, I would say I think in the coming year we ought to endeavour to ascertain the facts which are involved in this question, and be prepared, either in the shape of papers or some other form, to set our minds together and come to some reasonable conclusion upon a subject which is not only so interesting to the public, but which is of such vital importance to the gas companies.

Gentlemen, I had intended to say a few words to you in reference to the utilization of the residual products of gas, but I am happy to say it will not be necessary, as we are promised a lecture this evening upon that subject, by Dr. Letheby, which I am sure will be of a most interesting and instructive character. This has now become a more than usually interesting topic, inasmuch as very much of the debate now coming on in Parliament with respect to the price which the London companies are to charge for their 10,000 millions cubic feet of gas per annum, depends upon the amount of returns which they may obtain for their coke, tar, and ammoniacal liquor. Now I know that in consequence of the peculiar form which the legislation of the Upper House takes, whatever may be the result in London, will, more or less, and very shortly, become the result in the provinces. It is, therefore, very important that during the ensuing year, we should ascertain with greater exactitude than perhaps we have hitherto been accustomed to do, the value of these products, the best way of manufacturing them, and the best way of utilizing them.

There is one other matter, which, though it is not desirable to omit, I shall only make slight reference to. It is a question which very deeply concerns gas companies—viz., the mode of ascertaining the rateable value of gas-works. It is a subject which was thrown out for consideration last year, and which, I dare say, has been very seriously considered by most of you, although it has not taken any distinct form of result. I think during the next year it will be necessary that some action should be taken with regard to so grave a question. In all parts of the kingdom gas companies are being unduly pressed upon—and the public do not sympathize with them in the least—in consequence of the amount of assessment which, under the new legislation, is imposed upon them. In many cases their rates have increased three or four times, and it happens—I know it as a general fact—that though the law says the rates shall be equal throughout the whole of the community assessed, yet, in the present unsatisfactory position of this question, there are cases in which the rates upon the gas companies have become seven times as great as the rates levied upon the tradesmen and manufacturers in the same locality. This is a very serious matter, because it can only have one of two results; it must either increase the price of gas to the consumers, or it must diminish the dividends of those who have invested money in these undertakings. As a general rule, it will, undoubtedly, increase the price of gas to the consumers. It is the result of all the political economy of these subjects, that if the producer of any commodity has his production made more expensive to him, the purchaser of that commodity must in the end pay more for it. But the effect of it is also felt in another direction, and it is a serious one to be considered by the consumers of gas—viz., that they are made, in this form, to pay a very large proportion of the rates of the non-consumers. If every one consumed a rateable proportion of gas the question would be immaterial, except to the companies, and if they could raise the price of gas it would be immaterial to them too. But it is no longer immaterial when it occasions an unjust and unfair taxation of one part of the community for the benefit of another. This is a matter, as I said, of great interest to the gas companies, and one which may very well, in the ensuing year, receive considerable attention from the managers of their undertakings.

I have now, gentlemen, said all that I intended to say upon the progress of matters during the past year which are immediately interesting to you, and I wish only to add that as you have done me personally some honour in holding your meetings here, I should be glad to point out to you that this town is well worthy your attention in many respects other than those connected with the manufacture of gas. It is a very ancient town in one portion, and a very modern town in another; it is surrounded by extensive and beautiful scenery; it contains in its immediate neighbourhood nearly all the minerals which are commercially available in this country, and which you may have the opportunity of seeing; and it possesses some of the finest architectural constructions—as, for example, Wollaton Hall, and other buildings of mediæval times—which it is possible to conceive. If you can so arrange it, after the transaction of the business of the association, as to devote a day or two to the inspection of the neighbourhood within about fifteen miles, you will be amply repaid for your labour. There is only one other matter, and perhaps it is of less importance, though it is not to be despised. I hope you will honour me with your company to dinner at five o'clock to morrow.

Mr. G. T. Livesey, engineer of the South Metropolitan Gas-Works, then read the following paper

## ON THE PRACTICAL WORKING OF THE LIQUOR SYSTEM OF PURIFICATION.

*(Being a statement of results in continuation of the paper of last year on "An Improved Method of Purifying Coal Gas.")*

Without recapitulating what was read last year, I may shortly state that the liquor system of purification is based on the fact that ordinary ammoniacal liquor has a great affinity for sulphuretted hydrogen, and providing a plan can be found that will readily separate the sulphuretted hydrogen from the ammonia, a very effective purifying agent is at once obtained.

The plan I have adopted for this purpose is as follows:—The gases produced by the combustion of coke in the retort furnaces contain a considerable proportion of carbonic acid, which, having a greater affinity for ammonia than sulphuretted hydrogen, will, on being brought into contact with the foul liquor, displace the sulphuretted hydrogen, and produce a carbonate of ammonia which it is found is nearly, if not quite as effective as a purifying agent as the caustic ammonia.

To effect the purification of the liquor a 12-in. pipe was laid from the chimney-shaft of the retort-house, to convey a small portion of the gases of combustion, first, through a condenser composed of a number of 3-in. pipes, with water trickling over them, to reduce the temperature as much as possible (for the colder the smoke the smaller the quantity of ammonia driven off from the liquor to be purified or desulphurated); the cooled gases then pass on to an exhauster, which has merely to draw them from the chimney and to send them through the liquor-scrubber; and here, before describing the scrubber, I may say that I simply used a Beale's exhauster because I had it, for I am not sure it is the best thing I could use for the purpose, as there is a small proportion of sulphurous acid in the gases from the chimney, which may corrode the rubbing surfaces. If I were going to purchase entirely new apparatus I should try a closed fan, as the resistance to be overcome is very trifling—not exceeding an inch of water—and I think it would act better, and certainly cost less.

After my extended experiments of last year, which warranted the outlay necessary for adopting the process, there was not time to erect iron scrubbers by the end of the year, at which time the oxide contract expired, so to economize both time and money a pair of brick scrubbers were built of the following dimensions:—Inside diameter, 17 ft. 6 in.; height, 28 ft.; thickness of brickwork, 14 in. Covering on top, 1½-in. boards, grooved edges fitted with iron tongues, well tarred, and thus made perfectly tight.

The inside was lined with Portland cement, and covered with two coats of tar; this is also found to be tight.

These scrubbers were built over an underground tank which had been used for storing tar, and now appropriated to the desulphurated liquor as it flows from the scrubbers.

Above the brick scrubbers is placed an iron tank, of a capacity of about 16,000 gallons, to supply them with foul liquor.

A 5-in. pump, 19-in. stroke, is used to pump the foul liquor from the wells under the gas-scrubbers and elsewhere into the tank over the brick scrubbers. Three 4-in. pumps, 12-in. stroke, are fixed, to be used as wanted, to pump the purified liquor into an elevated tank to supply the gas-scrubbers. These pumps were required in connexion with the gas-scrubbers before the liquor process was introduced. I do not think they or the 5-in. pump will be quite equal to the full work next winter, unless I work them at a greater speed; they have been making about 18 or 20 strokes a minute—they are all single acting.

No separate account of the cost of the above apparatus has been kept, but the following statement is not far wrong:—

| | |
|---|---|
| Brickwork and plastering for two scrubbers . . . . | £240 |
| Tank to supply them with liquor . . . . . | 140 |
| Wood coverings to scrubbers and tank . . . . . | 25 |
| 5-in. pump and machinery to drive it, and exhauster . | 45 |
| Estimate for labour in laying pipes, fixing exhauster, &c., and value of old materials that were brought into use . | 150 |
| | £600 |

The gas-scrubbers were not erected for the purpose of applying the liquor purification; they are four in number, 24 feet high by 16 feet diameter, and under each one is a brick tank for liquor.

These scrubbers are to be increased in height by 4 ft. 6 in., and then I anticipate they will be fully equal to the work of purifying the whole of the gas that can be made on the present works—about 120,000 feet per hour—the previously described apparatus having been designed for this quantity.

The mode of working may now be described. The tank above the brick scrubbers being filled, and kept filled, with foul liquor, the exhauster sends a current of chimney gases of about 30,000 feet per hour through one of the brick scrubbers; this is sufficient to completely purify about 1200 gallons of liquor, and accordingly a trifle under that quantity is distributed by an ordinary Barker's mill on the coke, with which the scrubber is charged. The liquor flows from the scrubber into the well below, from whence it is pumped into the elevated tank which supplies the gas-scrubbers, and this tank is always kept full, so that in the event of the pumps ceasing to act from any cause, there may be a supply of liquor in reserve for the purification of the gas.

The chimney gases, after desulphurating the liquor, are conveyed to another part of the retort-flue and burnt. I intend, first, passing them through a vessel with either diluted sulphuric acid or water, to absorb the small portion of ammonia that they take from the liquor; there will then be absolutely no loss of ammonia.

The gas to be purified is passed, first, through a scrubber, where it is washed with a stream of foul liquor; then through one or two others, supplied, as the case may be, with about 20 gallons per hour per 1000 feet of gas made of desulphurated liquor; and, lastly, through another, into which a very small stream of water is flowing.

The gas then passes through the oxide purifiers, or one or two of them, so that should the supply of purified liquor to the scrubbers from any cause fail, there would be no risk of sending out foul gas.

It was the beginning of March before the system was permanently put in operation; the make of gas was 70,000 feet per hour. Only one of the brick scrubbers was then available for purifying the liquor, consequently the quantity was not quite sufficient to completely purify the gas from the whole of the sulphuretted hydrogen; a supply of 1400 gallons per hour was wanted, while only 1100 gallons was available, so a small portion of the sulphuretted hydrogen passed on to be removed by the oxide, but the quantity was so small that, since the 10th of March, only one of the oxide purifiers has gone off, the gas made in the time being 98,695,000.

From the experience gained in the last three months, I have found the most economical method of working to be by using liquor sufficient to remove 90 to 95 per cent. of the sulphuretted hydrogen, leaving the remainder to be removed by the oxide through which the gas must pass, for it requires a larger proportion of liquor to absorb the last traces of the sulphuretted hydrogen.

Now as to the cost of working. Omitting interest on first outlay, this is very trifling. There has been only the oil used for lubricating the bearings of the machinery and the exhauster, the wear and tear of the same and the power to work it, but the money value of these items I have no means of estimating. The labour and supervision connected with the apparatus has been *nil*, for the foreman simply has to see that the pumps are working, and that the liquor is properly purified from its sulphur, and beyond this nothing has been required, except the labour of changing one purifier, which may be put at £3. This for upwards of 10,000 tons of coal is a rate per ton which is inappreciable.

The purification of the gas is effected without any diminution of the illuminating power, but I do not find that the troublesome sulphur compounds are removed to any greater extent by the purified liquor than they would be by an equal amount of washing with ordinary liquor. The pressure of gas on the exhauster is considerably lessened from the fact of the gas passing through a smaller quantity of oxide. Our gasholders give 5 inches, while the pressure on the exhauster outlet is 7 inches.

I do not think the details of the apparatus are quite perfect, but those who have had experience in adopting any new process will quite understand the little alterations and adaptations necessary to bring it into practical working.

Mr. Goddard said he thought the association were under obligations to Mr. Livesey for the communication he had just read, for the experiments which he had conducted, and for the elucidation of that beautiful law of compensation to which he had directed attention. After the carbonization of the coal, he availed himself of the carbonic acid gas flowing from the furnace and used it for desulphurating the liquor, and the liquor so desulphurated had a greater affinity for the sulphur which remained in the gas. But there was one subject which he (Mr. Goddard) hoped Mr. Livesey would still turn his attention to, so as to make the invention more valuable—viz., to ascertain how far he could utilize the sulphur removed from the liquor. He believed it would be found eventually that the sulphur so produced would be of nearly sufficient quality to make sulphuric acid, which would saturate the ammonia in the manufacture of sulphate of ammonia. If such a thing could be secured it would render Mr. Livesey's invention a perfect one.

Dr. Letheby said he thought the results would probably acquire greater value if Mr. Livesey would give the association some information as to the strength of his ammoniacal liquor before and after the treatment, so that it might be ascertained whether any additional absorption of ammonia took place when it was brought in contact with the gas. At first sight it seemed to be a contradiction, that a given material containing sulphur should, on the one hand, have its sulphuretted hydrogen thrown out by the gases of the burning coke (chiefly carbonic acid), and, on the other hand, upon being treated with the raw gases containing sulphuretted hydrogen, it should give up its carbonic acid and take up sulphuretted hydrogen. This, however, was no doubt a reaction intelligible enough to chemists, and was accounted for by reason of the different quantities operating under different circumstances, for when an ammoniacal liquor containing but little sulphuretted hydrogen was treated with the products of the furnace fire, it was readily explainable that, as much carbonic acid gas existed in the furnace gases, they acted upon the comparatively small quantity of sulphuretted hydrogen contained in the liquor, and so turned it out; but when the raw gas from the retorts, charged with much sulphuretted hydrogen, was brought into contact with desulphurated liquor, the reverse action took place. It was exactly the same kind of result as that obtained by passing steam over red-hot iron, whereby oxide of iron was formed and hydrogen set free, whereas the same hydrogen passed back again over the oxide, reproduced the original steam and the metallic iron. In the first case there was much steam and but little hydrogen, whereas, in the second, it was much hydrogen and but little steam. This, he thought, was the explanation of the process described by Mr. Livesey. But it seemed an important question as to how much ammonia was absorbed from the gas as well as sulphuretted hydrogen. If the ammonia was absorbed from the gas, the ammoniacal liquor must be considerably strengthened. Perhaps Mr. Livesey would be able to tell the meeting what was its condition after it had, so to speak, done its work, and before it left the hands of the operator.

The Chairman said there was another subject upon which Dr. Letheby could give the association a little information. Mr. Livesey stated that the bisulphide of carbon was not diminished by the process, whereas he (the chairman) believed that Dr. Letheby's experiments proved that there was a considerable reduction in the amount of this impurity. If he understood it correctly, the ordinary 20 grains was brought down to 2 grains, although at the expense of the illuminating power of the gas.

Mr. Livesey said his remark was only intended to convey the opinion that the purified liquor had no greater effect upon the bisulphide than the foul liquor.

Dr. Letheby said the main chemical actions which took place when the sulphide of ammonium and ammonia of ammoniacal liquor came into contact with bisulphide of carbon were these. In the first place, the bisulphide of carbon, which was a sulphur acid, combined with sulphide of ammonium, which was a sulphur base, and formed a double sulphur salt that was dissolved and retained by the liquor. In the second place, the ammonia of the liquor slowly acted upon the bisulphide of carbon, and produced sulphocarbonate and sulphocyanide of ammonium, thus:—

$$\underbrace{4\,NH_3}_{\text{Ammonia.}} + \underbrace{4\,CS_2}_{\text{Bisulphide carbon.}} = \underbrace{2\,(NH_4\,CS_3)}_{\text{Sulphocarbonate ammonium.}} + \underbrace{NH_4\,C_2\,NS_2}_{\text{Sulphocyanide ammonium.}}$$

And after a time the sulphocarbonate of ammonia was resolved into sulphocyanide of ammonium and sulphuretted hydrogen, thus:—

$$\underbrace{2\,(NH_4\,CS_3)}_{\text{Sulphocarbonate ammonium.}} = \underbrace{NH_4\,C_2\,NS_2}_{\text{Sulphocyanide ammonium.}} + 4\,HS$$

In this manner it would be found that purified gas, containing ammonia, as it was delivered to the public, would form sulphocyanide of calcium by passing it through hydrate of lime; and no doubt the sulpho-cyanide of ammonium which was nearly always present in the water of the public meters was produced in this way. But he doubted whether, in bringing the raw gas into contact, not with free ammonia, but with carbonate of ammonia, as in Mr. Livesey's process, the same change would take place. He was inclined to think that the washing of the raw gas with the disulphurated liquor would not secure the removal of the bisulphide of carbon from the gas so well as the foul liquor would do it. The question, therefore, which Mr. Hawksley had suggested was a very important one, and it was a matter for practical working rather than for speculation.

Mr. Young referred to a case in which he was consulted on one occasion, where the oxide of iron purification was employed on the works, but the gas, although it left the purifiers in a proper state, was found to be very impure in the town. It turned out upon experiment that the water in the tanks of the gasholders was very impure with hydrosulphate of ammonia, so that the gas, after being purified from sulphuretted hydrogen, became contaminated from this source with a considerable quantity of ammonia.

Mr. Atkinson asked whether he understood Mr. Livesey aright, that the desulphurated liquor would not absorb sulphuretted hydrogen to a greater extent than pure water did. If so, he deduced from thence that the great value of the process was in the production of a stronger ammoniacal liquid than usual.

Mr. Livesey said Mr. Atkinson had misunderstood him. He said nothing about water, and he thought the misunderstanding had arisen from the paragraph in his paper to which the president had alluded. What he said was that the desulphurated liquor had no greater effect upon the bisulphide of carbon than the foul liquor. He washed first with foul liquor, and then with the desulphurated, and afterwards with a little water, to remove the last traces of ammonia, and, with this ammonia, to take out the little sulphuretted hydrogen combined with it. His tests for bisulphide of carbon or sulphur compounds had been continued all through the past winter, while washing with foul liquor entirely, and also when he began to use the desulphurated liquor; and he had found, on taking the average, that the quantity of sulphur in the gas was as nearly the same as possible. He applied a good stream of foul liquor first in a scrubber, the effect of which was that, though as obtained from the condenser and hydraulic main it was comparatively weak, it took up increased quantities of ammonia and sulphuretted hydrogen, and so became stronger. He then took the liquor which had passed through the gas once and desulphurated it, afterwards using it as pure liquor in the scrubber, where it continued to absorb ammonia. The extraordinary thing in connexion with it was the fact mentioned by Dr. Letheby. He found that the liquor did not give up its carbonic acid to the gas, but that although the gas, which before entering the scrubbers might have 2 per cent. of carbonic acid, and on leaving them had that quantity reduced to half, yet the desulphurated liquor took up ammonia just as it would

if it had not been desulphurated. The liquor going into the scrubbers was of 6 or 7 ounces strength, and it might on coming out be 1 ounce or 1½ ounce stronger.

Mr. Geo. Anderson, of London, read the following paper:—

ON THE EXTRACTION OF AMMONIA FROM GAS, AND THE UTILIZATION OF THE PRODUCT.

I propose to draw the attention of the society to the desirability of removing ammonia from the gas in manufacture, and to the readiest and most commercial plan of turning the ammonia so extracted into money.

Of the desirability of doing so I have no doubt, for next to an abundant supply, nothing so much tends to the extension of our business as a due attention to the manufacture of gas of a quality that can be introduced, without detriment, into every room in our dwellings.

If ammonia exists in any considerable quantity—that is to say, if nothing beyond the condenser and the lime or other purifier for the extraction of sulphur is employed, even if the ordinary scrubber is added, which merely consists of a vessel filled with some rough material that is only removed at distant and uncertain intervals, perhaps getting a flush of water occasionally, but under no systematic arrangement—the gas will contain such an amount of ammonia as will lessen its illuminating power, and will act to the destruction of brass fittings; will quickly destroy several important parts of the meters, and this destruction causes leakage and offensive odours, and consequently tends to earn a bad character for gas which hinders its introduction, besides giving the gas company a very considerable amount of trouble in making good the every-day defects which occur.

These remarks more particularly apply to provincial works, for in a great majority of these, more especially in the smaller towns, the extraction of ammonia is not attended to as the extraction of sulphur is, for reasons that will be referred to hereafter; and in such towns it is very usual for the gas company to attend to complaints.

But, in addition to the scientific value of removing ammonia from the gas, there remains the commercial question and also the sanitary one.

Numerous gas companies find their ammoniacal liquor a nuisance, and the respective communities they supply are universally getting more sensitive in the nose, so that unless it can be sold or given away, the question of what is to be done with it is becoming every day most urgent.

As respects the best mode of removing ammonia there is a conflict of opinion, and that mode which may be found the best in large works, is sometimes not so suitable in small works.

For instance, some manufacturers employ an acid and convert the ammonia at once into a solution, it may be of sulphate or muriate of ammonia.

I have employed these methods, and in large works they have answered commercially, but in small works they will not pay, and therefore they are not the best means under the circumstances.

Most members are, doubtless, aware of the interest that has attached of late to the quantity of sulphur which in some works escapes the ordinary means of purification, and of the bearing which the action of ammonia has in reducing that amount of sulphur, so that any mode which extracts the ammonia, but retains the sulphur, might be a very questionable operation.

I will now describe the means which I employ, and which I may designate as Lowe's process, with some adaptations of my own.

After the first process of condensation, which I prefer to make very gradual by running a condensing-pipe first along the inside and then along the outside of the retort-house, the gas passes to the ordinary condenser and thence to the washer.

This washer consists of an oblong vessel with several false bottoms or trays, each containing a few inches in depth of ammoniacal liquor.

Cross partitions with serrated edges dip into the liquor in each tray, so that the gas in passing is divided into small globules, so as to present great surface of contact with the liquor.

Means are provided, by small connecting-pipes fixed on the sides externally, to regulate the amount of pressure to be given by each tray, and to keep this uniform while the amount of gas passing is continually varying.

The stream of ammoniacal liquor is supplied at the top, passes from tray to tray, and escapes at the bottom; the gas, on the contrary, passes from bottom to top.

From the washer the gas passes to a vertical scrubber.

This scrubber is constructed as most modern scrubbers are, and contains several barred open trays, but their construction is somewhat novel, the object being to prevent the water, which has been equally spread at the top, ever collecting in a body and descending by one channel while the gas may be ascending by another and an easier one where there is less water.

As these trays are constructed it is impossible for the water to descend but where I have designed it shall do, and therefore in the depth of this tall column we have, as often as we choose to place them, a self-acting never-failing equal distribution of the purifying material.

This scrubber I supply with weak ammoniacal liquor, or with pure water, and when using ordinary Newcastle coal I prefer pure water in the quantity of 8 to 12 gallons for every ton of coal being carbonized.

The mode of supplying the water is by a Barker mill, first proposed, I believed, and employed by Mr. George Lowe, at the Chartered Gas-Works, about the year 1842.

This is a drawing of Lowe's scrubber, enlarged from the engraving that accompanies the specification to his patent.

Mr. Lowe employed two Barker mills, one at the top for the pure water, and one in the middle for the ammoniacal liquor.

This, at that time, was, I think, the best apparatus that could be employed, as exhausters were scarcely known and certainly not used, and therefore as washers threw a considerable pressure on the retorts, were very objectionable. Here permit me, as I am sure you will, to pay a tribute of respect to that gentleman, now the oldest veteran, and, next to Mr. Clegg, one of the most active men that have ever shone in that profession to which we are all attached, and one who, although removed from amongst us by age, still takes a lively interest in all we are doing.

It is impossible to economically supply such a stream of water as will keep a Barker mill constantly revolving without so diluting the liquor as would render it useless for conversion into salts; besides I have doubts of the advisability of such a stream of water being brought into contact with the gas. I, therefore, apply a tilting apparatus, which is fed at any desired rate by means of a tap, and by emptying its contents instantly causes the mill to revolve till the charge is distributed; this tilting I prefer to occur every 10 to 15 minutes, according to the quantity of gas passing.

I have tested the gas for ammonia in its various stages through the apparatus, by ascertaining how many feet of it was necessary or required to saturate a given quantity of sulphuric acid. In each experiment the test was the same—viz., 49 grains of sulphuric acid, made into a solution with distilled water, reddened with litmus, placed in a Woolfe bottle charged with small pebbles, and the gas allowed to bubble through at the rate of not more than 1 cubic foot per hour, until the liquid assumed the well-known tint of saturation by ammonia; a piece of reddened litmus paper being also inserted in the outlet to prevent ammonia escaping unobserved.

The number of feet of gas necessary to saturate the above quantity of acid was as follows:—

| | |
|---|---|
| Inlet of washer | 12·5 |
| Outlet of first tray | 15·5 |
| Ditto second tray | 25·0 |
| Ditto third tray | 28·0 |

Here the gas enters the scrubber.

| | |
|---|---|
| Outlet of scrubber when charged with 3-oz. ammoniacal liquor | 28·0 |
| Ditto when charged with pure water | 73·0 |

The gas was next tested by the photometer, by burning the gas of the inlet of the scrubber against the gas of its outlet simultaneously at opposite ends of the bar, and to check the experiments the test-meters and burners were reversed.

In each case, whether when using ammoniacal liquor or water in the scrubber, the gas of the outlet was superior to that of the inlet, in the proportion of about 6·5 to 7·2; that from the pure water being quite as good as that from the liquor, so that the use of water to the extent named did not seem to injure the illuminating power.

I may here mention that with the scrubber in action, in addition to the washer, the lime in the purifier lasts very much longer, and when taken out has much less odour.

The test for bisulphide of carbon was made after a method described in the *Chemical News*, because it can be made in a few hours, and solely on that account was employed instead of the more elaborate, but more tedious, method of Dr. Letheby.

By this mode the gas is caused to bubble through a solution formed of 5 drops of acetate of lead and 60 drops of ammonized alcohol, until the solution assumes an orange colour, and a dark brown precipitate is formed.

When the gas was being washed by ammoniacal liquor in the scrubber, of the strength of 2 ounces, the solution changed colour when 1·5 foot had passed through, and when pure water was substituted for liquor it did not change colour until 4 feet had been passed.

These results I know are at variance with some opinions on the subject both as to the effect of water in reducing the illuminating power, and in the efficacy of ammoniacal liquor in diminishing the quantity of bisulphide of carbon. I have therefore determined to prosecute them more fully, and if I arrive at a contrary conclusion, shall ask permission to state it to the society.

I will now describe the apparatus for converting the ammoniacal liquor into sulphate.

By the aid of a pump worked by the steam-engine the concentrated liquor is raised and delivered into a tank sufficiently high to run from it into a still, below which fire is applied, and the ammonia passes off through the still-head into a lead pipe laid horizontally in a lead-lined tank containing some acid solution.

The salts form in the bottom of this vessel, and are fished out and laid on a sloping table to drip, from whence they are taken to store. When the liquor has been boiled down to about ½-oz. strength, it is run into a tank, the bottom of which is a foot or two above the ordinary ash pans, and from this tank a pipe is laid with taps and branches—one to each ash-pan.

During the boiling process a considerable quantity of steam comes over with the ammonia, and it is important that the acid tank be constructed within a few feet of the still, otherwise this steam will condense and form water, and prevent the formation of salts; and therefore, to get rid of this steam, we enclose the tank with conveniently hinged doors to open when removing the salts; and from the top of the wood covering passes a pipe communicating with one of the flues leading to the chimney.

By the foregoing arrangements no vapour escapes, so that any one standing 10 feet from the apparatus would be unable from the smell to detect what operation was being carried on.

I do not hold out the process of manufacturing salts of ammonia as a profitable one for companies who can sell their liquor at, say, 2s. per 100 gallons, neither do I wish it to be understood as one that will entail a loss.

The process will in most cases be self-supporting, while in works making 20 million feet of gas per annum and upwards there will be a profit.

My chief object in bringing it under the notice of the society is to show the means by which ammonia—now a nuisance, and, it may be, an expense—may be got rid of without being either the one or the other; and I may also state that in some cases it would pay the gas company to convert its liquor into salts, while it would not pay a manufacturer five miles distant to remove it, even if he could have it for nothing; and with respect to the desirability of removing ammonia from the gas, many a one would do so, but that he would thereby increase the bulk of his liquor, which is already an incumbrance. If, therefore, I have shown how both may be attained—the removal of the ammonia, and the utilization of it afterwards—the object I had in view will have been attained.

Mr. Livesey inquired whether the writer of the paper really thought that the liquor supplied to a scrubber filled in the ordinary way with coke would pass down to one place, or whether it was only imaginary. He knew it was generally said that the liquor would pass down by one channel and the gas by another, but he did not find it to be so.

Mr. Anderson said he not only thought so but knew that such was really the case. He had attended to the opening of the scrubbers, and had seen certain sinuous channels through the coke, which channels were glutinized over with tar.

Mr. Cathels thought it was a great mistake to construct scrubbers of the immense size they sometimes met with. Scrubbers 4 or 5 feet in diameter were sufficiently large, and he preferred the use of boulders to coke.

Mr. Anderson said the more he studied the manufacture of gas, the more he was inclined to have the apparatus larger than he had ever had it. This was especially the case with reference to lime purification. A purifier of a given size would purify 5000 cubic feet of gas to the bushel of lime, but if it were made larger it would purify 10,000 feet. He had tested this and knew it to be the fact. At the Dover works he had purified 5 or 6 million feet of gas since the purifiers were charged; they were 24 feet long by 12 wide and 5 or 6 deep. But the quantity of gas made at that station might be purified in a purifier 4 or 5 feet square. He attributed the circumstances of the lime lasting so long to the gas passing through it very slowly and

having plenty of time to mingle therewith. He believed the same principle applied to every thing connected with gas purification.

The CHAIRMAN asked what quantity of coal in tons Mr. Anderson would purify with a ton of lime, and what was the character of the coal.

Mr. ANDERSON said he did not do it by the tons. The coal used was Pelaw Main, Washington, South Pelaw, and ordinary Newcastle coal. Up to the previous week the purifier had purified 21,000 feet of gas per bushel of lime.

The CHAIRMAN inquired the weight of a bushel of lime.

Mr. ANDERSON said it was 22 strike, or 18 heaped bushels to the yard. He could not put it into tons, but approximately a yard would probably weigh 17 cwt. or 18 cwt. As he had stated, up to the present time they had purified at the rate of 21,000 cubic feet of gas per bushel of lime.

The CHAIRMAN remarked that would be about 400,000 cubic feet to the ton—40 to 1 in round numbers; 40 tons of coal to 1 of lime, dry purification. He asked whether the gas was washed before it went to the purifiers.

Mr. ANDERSON said it was first passed through the four trays of the washer and afterwards through the vertical scrubber, using from 10 to 12 gallons of water. Practically, by the process he described, he had doubled the quantity of his ammoniacal liquor.

The CHAIRMAN asked whether chalk or stone lime was employed.

Mr. ANDERSON said it was chalk lime, from the Dover Cliffs.

Mr. METHVEN said his own experience in some measure agreed with that of Mr. Anderson. He found that in winter he could purify much less gas with a ton of lime than in the summer. But he could not at any time purify so much gas per bushel as Mr. Anderson had stated to be the result of his working.

The CHAIRMAN asked Mr. Methven whether he could give any proportions.

Mr. METHVEN said he used a small proportion of the lime in the retort-house, as well as for the purification, and he found that he purified about 9000 feet of gas per bushel in the summer, but only about 8000 in the winter.

The CHAIRMAN remarked, that was about twice the quantity of lime.

Mr. METHVEN said it was, but he had no washer. His coals were Pelaw Main.

Mr. ANDERSON asked whether Mr. Methven washed his gas?

Mr. METHVEN said his gas was washed in a peculiar way. It was sometimes washed, and sometimes not washed. In fact, he was just in the difficulty which Mr. Anderson described at the close of his paper. He did not want more liquor than he could possibly help, as he could not get an outlet for it, nor could he dispose of it, on account of the cost of carriage, and he was unwilling to have a smell upon the works. If Mr. Anderson's apparatus had all the advantages which he attributed to it, there was no doubt it would be a great benefit to many works situated as his were; but he very often found that though these things were suitable for some works they were unsuitable for others.

Mr. GODDARD apprehended that the great advantage of any apparatus for removing ammonia would be to realize the largest amount contained in the coal. Now he found it laid down as a principle that Newcastle coal would yield 34 lbs. of ammonia per ton, and he wished to ask Mr. Anderson what proportion he realized by his process of washing and scrubbing.

The CHAIRMAN: In what form of ammonia do you estimate the 34 lbs.?

Mr. GODDARD: As sulphate of ammonia.

Mr. ANDERSON: I could not answer that question because I have not made the calculation. I have upon some occasions produced 200 ozs. of sulphate of ammonia from a ton of coal, but I have not made any general calculation.

The CHAIRMAN: That is only 12½ lbs. Had we not better get these figures right? The 12½ lbs. is so great a contrast to the 34 lbs., that there must be some reason for it. Are you both speaking of the same description of coal?

Mr. ANDERSON: I know that if you use an acid in the purification of gas, you may get 10 gallons of 30-oz liquor from a ton of coal as a result throughout the year, but I do not think you will get that with pure water.

Mr. GODDARD: I should like to know what strength of liquor Mr. Anderson gets by his process.

The CHAIRMAN: However it is done, if it is obtained there ought to be either 34 lbs. or 12 lbs, because you both measure into sulphate, so that perhaps there is some error in the figures.

Dr. LETHEBY: May I say where I think the discrepancy lies? Mr. Anderson loses a large portion of his ammonia by running it away, partially distilled, into his furnaces. The calculation of 34 lbs. of sulphate of ammonia per ton of coal, is upon the supposition that the whole of the ammoniacal liquor is treated so as to get the whole of the ammonia. But in Mr. Anderson's process the residuum in the still runs away, and is lost altogether.

The CHAIRMAN: That does not quite explain the matter, because there is as great a difference as 3 to 1 between the two. When Mr. Anderson stated that fact he said his loss was very small. Now he cannot lose two-thirds by his process.

Mr. ANDERSON: I explained that I ran off the liquor when a whole gallon would be saturated with half an ounce of acid.

The CHAIRMAN: That would be only a twentieth part—5 per cent.—which does not account for much. Therefore we have nearly the whole still unexplained. It must arise from some error of figures which may be explained; it cannot be an error of fact.

Mr. ANDREWS: I believe it arises in this manner. Mr. Goddard's calculation is made on all the gas given off from a ton of coals, whereas Mr. Anderson's is upon the ammonia obtained from the ammoniacal liquor. A large amount passes over in the apparatus, which is not taken into the account.

The CHAIRMAN: I do not understand it to be a chemical calculation, but the result of a fact.

Mr. GODDARD: I have never realized such a quantity as 34 lbs., but I have heard of gentlemen who have, and my object in raising this question was to know how far the apparatus brought under our consideration was effecting the work it is intended to perform. I think our friend Mr. Esson could give us some information in reference to the quantity of ammonia which he has got from a ton of coal, and which would very far exceed the quantity set forth by Mr. Anderson.

Mr. ESSON: I reserve what I have to say.

Mr. LIVESEY: The quantity of ammonia sold by the company which I represent, taking the years through, would be something like 20 lbs. of sulphate per ton of coals. I may mention that I find different coals produce different quantities. I have heard that Mr. Esson produces an extraordinary quantity of sulphate per ton—something like 30 or 36 lbs. We can only sell liquid that will produce sulphate to the extent of about 20 lbs. per ton.

The CHAIRMAN: What coal is it?

Mr. LIVESEY: Dean's Primrose principally.

Mr. CATHELS: I may suggest that one possible explanation is that while Mr. Livesey is using Newcastle coal, Mr. Esson is using inland coal.

Mr. ESSON, of Cheltenham, read the following paper:—

### ON THE MANUFACTURE OF SULPHATE OF AMMONIA.

A wish has been expressed that I should say something on the manufacture of sulphate of ammonia; I shall accordingly briefly describe some of the processes adopted for the manufacture of that article. It is desirable that the ammoniacal liquor to be used should be as strong as possible, certainly not less than 7½° of Twaddle's hydrometer, or about what is termed 15-oz. liquor. If a first-rate quality of sulphate is wanted, then the acid used should be wholly made from limestone, and generally known as brown acid, of about 1·750 specific gravity. Under these conditions sulphate of ammonia can be manufactured within one-eighth per cent. of purity (pure contains of ammonia 25·75 per cent.; as generally made at Cheltenham, 25·625 per cent). The simplest process I know of is to saturate with sulphuric acid the ammoniacal liquor in a leaden cistern. This operation requires to be performed with care. The cistern should be covered, and an outlet for the escape of the sulphuretted hydrogen made to communicate with some fireplace or chimney-stack. The mixture requires to be gently agitated for some time with a rod through a small opening in the cover. When the emission of the gas has ceased the mixture is to be tested with limus paper, and more acid or liquor added as the test may determine. On the proper tint being obtained the saturated liquor is then ready to be run into an iron boiler for the evaporation of the surplus water. The boiling should be continued until Twaddle's hydrometer shows a specific gravity of 52°; the fire should then be withdrawn, and the contents of the boiler permitted to cool and the salts to form. The salts may then be ladled out and put into proper draining vessels, the drainage being collected and again put into the boiler. The sulphate of ammonia thus made will have an iron or dark colour as the mixture has had an excess of ammonia or acid. Although not equal to the beautiful article produced by apparatus of better construction, sulphate of ammonia so made is quite good enough for the manufacture of artificial manures; indeed, in many districts may be sold directly to the farmers. When gas-works are small and in out-of-the-way places this plan of manufacture may be adopted, and the salts readily sold at a fair price, and the thing pay as well as in larger establishments with proper apparatus. Salts so made mixed with four parts by measure of dried and riddled ashes, make an excellent spring top-dressing for grass or autumn wheat feeble from the severity of the past winter.

A step in advance in this arrangement is that one in which the ammoniacal liquor is run or pumped into a large boiler (an old steam-boiler, if tight and without internal flues, answers very well). Along with the ammoniacal liquor a proper quantity of shell lime is put, which sets firm the fixed ammonia. From this boiler a suitable pipe conducts the ammoniacal steam to a saturating vessel of proper construction, lined with lead, and into which the sulphuric acid is put; the salts formed in the saturator are removed as they form, and more acid added, as the case demands. The firing of the boiler is continued till all the ammonia has been driven off (to be ascertained by test-paper) and is then withdrawn, and the residuary water left to run off by a suitable cock or plug. It will be noticed that by this process the large quantity of water so run off forms the saving on the former process where it had all to be evaporated. The whole of the salts formed in the saturator and mother liquor and water are run or ladled into iron or leaden evaporating boilers or pans for the complete crystallization and cooking of the sulphate of ammonia. If this process be hastened by the application of heat and thoroughly closed, the crystals will be small and crisp; if protracted and by exposure only, the salts will be large. Sugar pans are often used with a fire under, but shallow vessels made of timber lined with lead, and heated by a coil of steam-pipe, are preferable, and enable the manufacturer to produce a better article. The salts when formed in either of these ways are ready for washing and draining, after which they may be packed for the market. In very few instances is washing resorted to, although a simple operation and necessary for the production of a superior article. The saturating-box in this arrangement is generally divided into two parts by a sealed partition, reaching within 6 inches or so of the bottom. One side is covered in, and the ammoniacal steam-pipe passes through the cover, and has its end open and immersed in the sulphuric acid. From this covered in portion of the saturating-box a pipe communicates with a furnace or chimney-stack, for carrying away the sulphuretted hydrogen evolved during the process of neutralization. There are several modifications of this plan, and upon the whole it may be made a very efficient apparatus, and white salts may be produced at a fair cost; there is, however, generally a considerable waste of ammonia. Now it is to be observed that if a thing be worth the doing it is worth the doing well. If ammonia is to be converted into a marketable form, it is just as proper to work it up with care as it is to conduct the production of the staple article in a gas manufactory with care and economy.

So far as I can learn the amount of sulphate of ammonia obtained from each ton of coals carbonized is somewhere about 16 lb. Now, with no extraordinary care, nor any peculiar quality of coal, nor any very unusual treatment of gas in the process of purification, about double that quantity of sulphate of ammonia can be produced from each ton of coal carbonized. The increased quantity is partly gained by washing or scrubbing the gas, and by using an apparatus for the production of ammoniacal salts of a character not permitting of any waste. I shall now endeavour briefly to

describe such an apparatus. I believe Mr. Laming was the first to use, if not the inventor of, the columns or slices arrangement; the apparatus has, however, undergone many modifications, suggested by experience, since first brought into use. The ammoniacal liquor having been wrought up to the proper strength by scrubbing, the gas is gradually pumped into a larger cast-iron cistern well covered in. It is convenient to have the cistern at a considerable elevation. The liquor is allowed to settle, and is then pumped into a higher and smaller cistern placed in a position near to the still-columns, and at an elevation of about 12 feet or so above them. This cistern is kept continually full when the apparatus is at work, that a uniform head or pressure may be maintained on its outlet. To attain this end the pump is made to deliver slightly in excess of the quantity being used, such excess returning by an overflow into the lower or larger cistern. It is well to have a counterbalance float working in the head cistern, so that the workman in charge may notice any deficiency in head that may occur. From this head cistern one or more pipes of suitable size communicate with the top of the still-columns through which the liquor is discharged and regulated as to quantity by suitable stop-cocks.

The still-columns resemble Coffey's stills. They are vessels rectangular in horizontal section, from 18 feet to 25 feet high, by 6 feet to 10 feet wide, and about 1 foot to 2 feet in their other dimensions. They are made steam-tight, and may be of iron or timber. Internally there is a series of iron shelves about 3 feet apart, extending from about 6 feet of the top to about 2 feet of the bottom. The ammoniacal liquor is admitted as before-mentioned at the top, and descends by a series of traversers on the iron shelves until it reaches the bottom. The 2 feet space at bottom is kept half filled with the resultant liquid. Near the bottom of this space and into the liquid, steam at a pressure of about 20 lb. to the square inch is admitted by a pipe, and controlled as to quantity by a tap in the pipe; the steam works its way out of the liquor, and passes upwards between the iron shelves and through the ammoniacal liquor pouring over their ends and over the surface of that contained on the shelves. In this manner the pure ammonia is vaporized, and emerges from the columns by a pipe into the still-head, and thence onwards to the saturating vessels. The saturator is a vessel made or lined with lead of from 100 to 200 cubic feet capacity. The saturators are made of various forms. The form I prefer is cylindrical, with a hemispherical top and flat bottom, and having ample space allowed for expansion of parts in the sustaining framework of wood. On the top of the dome is a man-hole and door for admission to clean and repair. The ammoniacal steam-pipe from the columns enters the side, and is formed into a semicircle resting on the bottom, and it is perforated with a number of ¼-inch. holes. Near to the saturator, and rather above its level, is the charging-box, being a wooden vessel of rectangular form lined with lead; into this vessel is poured the salammoniac, and which, before being conveyed by a sealed lead pipe into the saturator, is diluted with water to the extent required to prevent the formation of salts in the saturator. The control of the discharge through this connecting-pipe is maintained by means of a short piece of white india-rubber tubing with a screw-clip for enlarging, or diminishing, or stopping the passage at will. When the saturator has been charged from the charging-box and the ammoniacal liquor turned on to the columns, the ammoniacal steam then enters the dilute acid and becomes fixed.

This process, as is well known, disengages sulphuretted hydrogen gas of deadly properties. I may by-and-by show how this sulphur can be utilized, but meantime desire to say that it can be so treated as to give no trouble. A pipe of suitable dimensions leads from the top of the saturator to a condenser, through which all the noxious gases are passed, and the portions condensable, by exposure to cold become liquid. This liquid is inodorous and innocuous, and is separated from the gas in a severed separating-box. The liquor may be run into the furnace ash-pits or into any common sewer, and the gas conveyed by a suitable pipe through the brickwork forming the side of a boiler or other furnace about 4 inches to 6 inches above the level of the furnace-bars and near to the front, and then utilized in the form of a burning gas to aid the fire. This deadly gas being thus easily got quit of, the manufacture of the salammoniac, so far as my experience goes, can be carried on without giving the smallest nuisance. It is here, however, to be observed that this mode is attended with the waste of the sulphur. The saturator has near to the bottom a suitable pipe for discharging the contents when ready into a rectangular wooden vessel lined with lead, called the settling-basin. The settling-basin is placed in such relative level to the saturator and the evaporating-basin as to receive from the first and discharge into the last. In the settling-basin the neutralized liquor remains until all the impurities that will fall by gravitation to the bottom have done so, and is then decanted into the evaporating-basin. Reverting to the still-columns, it will be remembered that the ammonical liquor is run in at the top and the steam enters at the bottom, and that the steam in passing upwards evaporates the free ammonia and carries it onward and upwards in the form of steam to the still-head and saturating vessel. A considerable amount of water collects in the bottom space of the columns, and has to be run off in a continuous stream. This water is run into closed vessels, and is then treated with shell lime and agitated by machinery. Under such treatment it yields fully 15 per cent. more of ammonia. The ammonia steam evolved from the lime-boxes is conducted by a pipe to a vessel containing sulphuric acid, and its open end seated in the acid, and so fixes the ammoniacal steam. A separate still, colnmns, and saturator is provided for the production of the caustic ammonia. A pump wrought by the steam-engine pumps the liquid caustic ammonia from a settling-vat, into which the liquor is run from the lime-boxes, into the top of the lime-still column. Steam is admitted at the bottom of the still, as in the other stills, and in its progress from the bottom to the top carries with it the evaporated ammonia onwards to the caustic ammonia saturator, generally placed alongside the saturator already described, and containing dilute sulphuric acid, changed in a similar manner to that employed for the other saturator, and by an independent sealed pipe from the same charging-box. The operation of the lime-still and saturator occasions no nuisance, as the steam evolved in the saturator is utterly harmless. The water runs in a continuous but properly regulated stream from the bottom of the lime-still to waste. It has no smell, and contains lime, which may be allowed to subside in a setting-well, and afterwards used for luting the retort-lids.

Upon the process of neutralization being completed in the saturator the contents of that vessel is discharged by means of a pipe into the settling-basin, and is treated in the same manner as already described for the other process. The operation has now been followed from the initiatory steps to the settling-basin; from that basin the saturated liquor is run into the boiling-down basins. These are generally made of wood lined with lead, rectangular in form, and about 12 inches to 16 inches deep. A long coil of 1 inch lead steam-pipe is laid in the bottom, supplied by 30 lb. of steam, and having a tap on the outlet. The steam used for the boiling down of the salts is generally partially condensed and again used as steam-boiler feed. The salts or salammoniac form under the process of boiling and as the surplus water evaporates. These salts are then ladled from these basins into a washing-basin; enough of mothers generally is carried along with the salts by washing them. That operation simply consists in agitating the salts in these basins by a rope-like instrument made of wood until quite white.

The salts as washed are ladled into draining baskets placed on planks laid across the washing-basins or on an incline, in either of which positions the mothers are drained into the washing-basin. In about twelve hours the contents of these baskets may be deposited in the stores. The mothers used for washing get very dirty. They are decanted into a steaming tube, into which at pleasure the used steam from the evaporating or boiling-basins can be turned. In a short time after this steam purifying process the impurities precipitate and the liquid becomes clear, and is then decanted into the boiling-basins. All dirty stuff containing any ammonia incident to the manufacture or collected at cleaning times is put into these steaming tubs, and so purified and utilized. The store-room for the salts has two floors, both slightly inclined to one point; the lower floor is lined with lead, the upper one is formed of open-jointed deals. The undischarged mothers is thus easily collected and are returned to the boiling-basins and utilized. The sweepings of the floors are taking to the steaming-tubs and cleaned, and again crystallized in the boiling-basins. It is to be observed, as before noticed, that in all of these described processes the sulphur is lost. Mr. Forens, of Old Ford, Bow Common, has patented, two years since, an arrangement and apparatus by which that product is utilized, and greater economy is obtained. The ammoniacal liquor just before being passed into the stills is heated by the sulplus sulphuretted hydrogen and steam passing out by a pipe before mentioned from the saturating vessel. This plan of heating the ammoniacal liquor has been long used in a somewhat different form by a Birmingham maker of sulphate of ammonia. The heating of the still feed tends to cool the eliminated gases of the saturator. These are subsequently further condensed in a water condenser, and then pass into the separator formerly described. The sulphuretted hydrogen being thus separated is conducted by a pipe into a sulphur furnace, in which a quantity of brimstone is burning. Nitrate of potash or nitrate of soda being also burning in the nitre furnace, the products of combustion from these two furnaces, in union with the dry sulphuretted hydrogen from the saturating vessel, result in the sulphurous acid and nitrous acid fumes which from sulphuric acid in the vitriol chamber.

The CHAIRMAN: What coal do you use?

Mr. ESSON: Midland coal, sometimes mixed with Welsh, and sometimes a little Staffordshire.

The CHAIRMAN: There are so many descriptions of Midland coal.

Mr. ESSON: Staveley coal generally.

Mr. ANDREWS, in answer to an inquiry by the chairman, said he had given up the manufacture of sulphate of ammonia, and found it was better to sell the crude liquor. The authorities in Swansea were very severe, and perhaps his process was not so perfect as Mr. Esson's. Complaints were made, and therefore he gave it up.

Mr. GODDARD said this was a subject in which he took a deep interest. He observed in Mr. Esson's paper that he used acid made from sulphur alone. He should be glad to know why he used acid made from sulphur in preference to acid made from pyrites. A great portion of the acid now sold was made from pyrites, and there was a great difficulty in getting acid made from sulphur. If it were an object to obtain a white sulphate, he could very well understand why the sulphur acid should be preferred; but, as he understood from Mr. Esson, the purpose for which his sulphate was employed was the manufacture of artificial manures, in which the question of colour was of no consequence whatever.

The CHAIRMAN said he thought that was the first described process, but Mr. Esson had described three, the last of which was most refined, and was for the manufacture of white sulphate.

Mr. Esson said that was so. He merely alluded in the first place to the way in which salts might be prepared for purposes in which colour was of no great consequence; but he had found that in using an inferior acid he could never make a superior sulphate. Moreover, there was always a portion of arsenic in it.

Mr. GODDARD said the manufacturers of artificial manures generally preferred the darker salts to the white salts such as Mr. Esson produced. He had had an opportunity of witnessing his process, which certainly was a very beautiful one, and produced salts which were very pure and white. He thought, however, that Mr. Arnott, who was present, and had had considerable experience in the manufacture of sulphate of ammonia, had adopted a plan by which he obtained an article quite as white with much less complication.

The CHAIRMAN said he knew what Mr. Arnott had done at Newcastle, and he was sure the meeting would be very glad to hear that gentleman describe his process. He would, however, first ask Mr. Esson whether he had made any other ammoniacal salts besides the sulphate of ammonia.

Mr. ESSON said he had never attempted to make carbonate, but on several occasions he had made a muriate. A very encouraging prospect was set before him, but the results were not satisfactory. He purchased the muriatic acid of the same strength as the sulphuric acid, but it cost too much money. The article delivered at a small charge was so weak that it led to a considerable amount of work. With his apparatus one man could produce about a ton of sulphate a day, whereas it would require double the time to produce the same results with muriate.

Mr. WARNER inquired the size of the building shown on the plan.

Mr. ESSON said it was 60 feet by 30, with lean to roof.

Mr. GODDARD asked whether any one present had used a Coffey's still in the preparation of sulphate of ammonia, and, if so, whether he could furnish information as to the result.

Mr. ESSON said the apparatus he exhibited was really a Coffey still. He might mention that his drawings were free to any one, and he thought they would be found sufficiently explanatory to enable any intelligent man to erect the apparatus.

Mr. SIMPSON wished to ask Mr. Esson whether he thought it was such a thing as would remunerate a company for the expense,

supposing the case of a small concern like that which he represented, where the make would be about 40 tons annually, and they had to remove the material from the works to some other place in the town.

Mr. Esson said the best way to answer the question would be to ascertain at what price they could sell the article after it was manufactured. For a small place, he thought the description of apparatus shown by Mr. Anderson would be the best and simplest. He had no doubt that in an agricultural district, where farmers paid a high rent, and were always willing to pay for a good manure, it would answer very well; but in a place where rents were low they would not give themselves the trouble to use it.

The Chairman said the question was whether, supposing the make to be about 40 tons of salts a year, it would be worth while to go to the expense of setting up an apparatus for the manufacture of sulphate?

Mr. Esson replied that out of that 40 tons upwards of £100 a year could be realized clear, after paying the expenses attendant upon the process. The apparatus, he supposed, would cost something under £100.

The Chairman: Not with your apparatus?

Mr. Esson: No.

Mr. Warner said at South Shields the facts which Mr. Esson had given were fully borne out in experience. Some few years ago the make there was somewhat similar in quantity to that mentioned by Mr. Simpson, and their profits were under £100.

The Chairman said in that case the liquor was worked upon the company's own premises. The question was about the removal and then working, and the additional cost thus occasioned. He presumed that Mr. Esson's object had been not only to obtain the best chemical results, and get all the ammonia possible, but also to prevent nuisance.

Mr. Esson said it had been.

The Chairman: Now, how far is your apparatus necessary for that purpose? Being a complicated one, where could it be stopped at so as not to be a nuisance? You have a repetition of processes; you catch not only the cat, but the little kittens. Where could you stop so as not to run the risk of being complained of for being a nuisance?

Mr. Esson: You would have to stop here [describing one of the diagrams]. All that you would have to abandon would be the settling, boiling, and washing business, which bears a very small proportion to the rest.

The Chairman: You would save, I suppose, half the apparatus, and lose 17½ per cent. of the salts?

Mr. Esson: There is no complication in the process, although the time I took to describe it might make it appear so.

The Chairman: It is not necessarily complicated, but multiplicated.

Dr. Letheby: I should like to ask two questions which pertain rather to the sanitary character of the operations going on than to the profitable nature of the working. The first is this: After your liquors are saturated, do you blow steam through the saturating vessels for a little while, to carry off any sulphuretted hydrogen present, before you draw off the liquors or not?

Mr. Esson: While the saturated liquor is being discharged from this vessel there is no escape of steam.

Dr. Letheby: You do not understand me. If the liquor be drawn from the saturation vessel with a little extra ammonia delivered to it, it will contain a small quantity of sulphuretted hydrogen, and when conveyed to the saturating vessel afterwards, this sulphuretted hydrogen will be given off. I want to know whether you take any precaution to guard against a nuisance in that way? Do you, before the liquor is drawn off from the saturating vessel, turn off the ammoniacal liquor and blow a little steam through it, so as to get rid of the sulphuretted hydrogen?

Mr. Esson: We have never done it.

Dr. Letheby: That leads to the second question. What plan do you adopt to know when the acid in the saturating vessel is just exactly saturated?

Mr. Esson said a small quantity was allowed to flow into a pipe, and test-paper was applied, but the workmen became so accustomed to the process that they had no difficulty in ascertaining the fact. They generally contrived to have it slightly on the acid side.

Dr. Letheby said in all the operations carried on about London by means of the Coffey still, the common practice was to turn off the ammoniacal liquor from the top of the still as soon as it was found that the acid in the saturating vessel was saturated, for ten minutes, and then to blow steam through the still for fear of the evaporating process giving off any sulphuretted hydrogen. The steam, after passing through the vessel, went away to the furnace flue as usual. There was a little plan for utilizing the ammoniacal liquor which he had seen at some small gas-works, which was simple and effective. The ammoniacal liquor was put into a common boiler, steam was blown into it, and then the sulphuretted hydrogen and ammonia was carried down into a peculiarly constructed saturating vessel containing strong acid, in which vessel a diaphragm was used, which completely prevented any escape. [Dr. Letheby described on the black board the construction of the vessel and mode of operation.]

Mr. Arnott said that was exactly the process he had adopted for several years.

The Chairman, in closing the proceedings of the sitting, said that instead of offering to each gentleman in succession, at the close of the discussion of his paper, a vote of thanks as on former occasions, it was intended to propose a general vote at the close of the session, which he thought would save the time of the members, and be equally gratifying to those whom it was intended to honour.

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In the evening, the following lecture was delivered before the association:—

## ON THE UTILIZATION OF THE WASTE PRODUCTS OF THE MANUFACTURE OF COAL GAS.

By Dr. Letheby.

Mr. President and Gentlemen,—I am afraid that the subject which we have met to discuss this evening is too extensive in its scope, and also too intricate in its details, to be examined very closely during the time at our disposal, and that we shall not be able to do more than study its principal facts.

As you are aware, the residual products of gas-making are six in number—namely, *coke, ammoniacal liquor, coal tar*, and the three waste products from the purifiers, as the *spent oxide of iron*, the *refuse lime*, and the *acid or other matters used for absorbing ammonia*, each of which has its special value on account of its technical uses.

### I.—Coke.

This need not occupy much of our attention, as its practical value and uses are pretty well known to you. I may say, however, that it was the opinion of the late Dr. Fyfe, and is still the opinion of many chemists who have examined the power of coal under steam-boilers, that the heat actually made available *in practice* is very nearly the same as ought to be produced *according to theory* by the quantity of coke which the coal yields. He found that a pound of Scotch coal from Trenant would boil away 5·61 lbs. of water, and that the coke of it, which amounted to 0·525 of a pound, produced 3·9 lbs. of steam; so that the practical loss was 5·61 — 3·9 = 1·71 lbs.; but the theoretical value of the coke was about 5·5 lbs. of steam. Here is a table of the relative heating power of different fuels, expressed in the number of pounds of water which 1 lb. of the substance will boil away when the water has been heated to its boiling-point:—

| | |
|---|---|
| Dry wood (average of many specimens) | 4·51 lbs. |
| Derbyshire coal (ditto) | 7·58 „ |
| Scotch coal (ditto) | 7·70 „ |
| Lancashire coal (ditto) | 7·94 „ |
| Newcastle coal (ditto) | 8·37 „ |
| Welsh coal (ditto) | 9·05 „ |
| Good coke (ditto) | 10·00 „ |

If all these numbers are multiplied by 5·5, they give the quantity of water which a pound of the fuel will in each case raise from 32° to 212°, and the results show that the thermotic power of coke is very high.

### II.—Ammoniacal Liquor.

This is the aqueous portion of the condensed products of the gas. It floats upon the tar, and is a watery solution of carbonate, sulphide, and sulphocyanide of ammonium, with certain carbohydrogens of no value.

If all the nitrogen contained in coal were converted into ammonia, so as to make a liquor of 8-oz. strength (4° Twaddle), it would yield from 142 to 226 gallons per ton of coal. This will be evident from the table which is before you, and which represents the average amounts of nitrogen in certain well-known coals in a dry condition:—

| | Nitrogen per Cent. in Coal. | Ammonia per Cent. from Coal. | Gallons of Liquor of 4° Twaddle p. Ton of Coal. |
|---|---|---|---|
| Welsh coal (average) | 0·91 | 1·10 | 142 |
| Lancashire coal (ditto) | 1·25 | 1·52 | 196 |
| Newcastle coal (ditto) | 1·32 | 1·60 | 206 |
| Scotch coal (ditto) | 1·44 | 1·75 | 226 |

But by far the largest portion of nitrogen is not converted into ammonia, for by combining with sulphur and carbon it forms the sulphocyanides which are so abundant in ammoniacal liquor and in spent lime, and much of it also unites with carbon and hydrogen to produce the alkaloids which exist in the tar. In practice, therefore, you get but a comparatively small proportion of the nitrogen as ammonia in the ammoniacal liquor. The quantity of liquor rarely exceeds 45 gallons of 8-oz. strength per ton of coals; and to obtain this quantity you must condense well, and also wash the gas with water. I have already explained to you how this is done at the Birmingham and Staffordshire Gas-Works by Mr. Hugh Young, who obtains 44 gallons of liquor per ton of Staveley coal in his yearly working. In ordinary practice the yield is about 25 gallons per ton, and in London it is not above 13 gallons—calculated in every case as 8-oz. liquor. You will see from this how largely the production of ammoniacal liquor may be increased; and I will call to your recollection the valuable advice of your president, Mr. Hawksley, with respect to the copious washing of raw gas with ammoniacal liquor, for this practice has a twofold advantage—it not only purifies the gas by removing tarry matter and sulphur compounds, but it also strengthens the liquor and renders it a more valuable product. By using the liquor as a shower or in a scrubber, in the proportion of 1 volume of liquor to 16 of gas, the liquor may easily be raised to 10° or 11° of Twaddle, which are equivalent to from 20 to 22 ounces of acid; and considering that the price of liquor rises about 4d. or 6d. per butt for every degree of Twaddle, it is manifestly of the greatest importance that the liquor should be sent away from the works as strong as possible. It ought, in fact, never to be under 6° of Twaddle, or of less than 12-oz. strength; and, with proper condensation and judicious washing, there should be from 29 to 30 gallons of such liquor produced from every ton of coals. The average price of ammonical liquor of 8-oz. strength, in eleven towns of England, is at the present time 2s. 7d. per butt of 108 gallons. It ranges from 1s. 9d. to 4s. 6d. per butt, and in London it fetches 2s., with an increase of 4d. per butt on every additional ounce of acid strength. Below 3° of Twaddle or 5oz. of acid it does not pay for working, whereas at 10° or 11° of Twaddle it is a valuable product. The strength of the liquor may be estimated either by the hydrometer or by the quantity of strong sulphuric acid (sp. gr. 1845) required to neutralize it; and it will be found that every degree of Twaddle is equal to about 2 ounces of acid per gallon of liquor.

The method of converting the liquor into a salt of ammonia varies in different places according to the facilities for working. In some places the liquor is at once saturated either with sulphuric or muriatic acid, in a close tank, and the evolved gases (sulphuretted hydrogen and carbonic acid) are carried to a furnace or to a furnace shaft. The saturated liquor is then evaporated and crystallized in open troughs. This, however, produces a dark-coloured salt which is not very saleable. The liquor, therefore, is either distilled alone from a steam-boiler, or it is mixed with lime in the boiler, so as to fix the sulphuretted hydrogen and carbonic acid, and is then distilled. In many works the liquor is heated in an apparatus called a Coffey's still, which is a tall vessel containing a number of transverse divisions (from 20 to 30) which alternately pass to nearly the opposite sides of the vessel. The liquor is run in at the top, and as it flows from side to side over the alternate divisions, in its way downwards it meets a rush of steam, which is admitted at the bottom of the vessel, at a pressure of from 20 to 30 lbs. upon the inch, and thus the carbonate and sulphide of ammonium are volatilized. In all these cases the ammonia is distilled into a

close vessel containing sulphuric acid, diluted with enough water to prevent the salt from crystallizing (equal parts of brown chamber acid of commerce and water are good proportions); and the evolved gas (carbonic acid and sulphuretted hydrogen) is conveyed to the furnace fire, or is used for the production of oil of vitriol. When the ammoniacal liquid is evaporated by blowing steam into it, it is necessary to have a worm, or other cooling apparatus, to condense the water from the gases before they are carried to the furnace, or they will perhaps extinguish the fire. While the distillation is going on the acid in the saturating vessel is frequently examined, and when it is thoroughly neutralized, it is run out into a proper receiver, and is then transferred to shallow pans or troughs, where it is evaporated to the crystallizing point.

The residual liquor from the stills is not completely exhausted of ammonia, but contains from 3 to 5 ounces of sulphocyanide of ammonium per gallon. It is, therefore, treated with lime, and again distilled, whereby more ammonia is obtained.

If there were a large demand for the sulphocyanide, it might perhaps be worth while to recover it from the spent liquor by evaporation, especially where it could be done by waste heat. Here is some of the residual liquor, and you will notice that when I add to it a very acid solution of a persalt of iron it produces a deep blood-red colour of the ferric-sulphocyanide. Here also is some of the salt obtained from the liquor by evaporation, and it is well suited for the preparation of this white powder, the mercuric sulphocyanide, which is the sole constituent of the little toys called Pharaoh's serpents. Sulphocyanide of ammonium is also used to some extent by photographers. I may here mention that the watery solution which runs from the hydraulic mains with the tar, when the temperature is not below 150° Fahr., contains this salt, without any carbonate or sulphide of ammonium; there is no reason, therefore, why this solution may not be collected, apart from the true ammoniacal liquor which is found in the condensers, for even if it be not of much value on its own account, it might be kept from diluting the liquor in the first stages of condensation, and be afterwards used instead of water for finally washing the raw gas.

In country gas-works, where there is little or no sale for ammoniacal liquor, it would not be difficult to convert it into sulphate of ammonia, by transferring it to an old boiler, then blowing steam into it, and carrying the vapours into a properly constructed vessel, charged with the brown sulphuric acid of commerce, diluted with the mother liquor of a previous crystallization. In this way every ton of coals should yield about 30 lbs. of sulphate of ammonia.

This sulphate is worth from £12 to £14 per ton, and it is not merely used for agricultural purposes, but it is the salt from which all other preparations of ammonia are obtained. Distilled with quick lime it yields pure ammonia, which by condensation in water forms the liquor ammoniæ of commerce; distilled with chalk it makes carbonate of ammonia; and it has other applications. There are good reasons, therefore, why great pains should be taken to recover all the ammonia of gas-making. We shall presently see how this may be further accomplished by means of absorbent agents placed at the end of the purifiers.

### III.—Coal Tar.

This is a very complex liquid, for it contains at least three classes of compounds—viz., acids, neutral bodies, and alkaloids, the composition and leading properties of which are as follows:—

*Acids of Coal Tar.*

| Names. | Formulæ. | Specific Gravities. | Boiling-Points. (Fahr.) |
|---|---|---|---|
| Acetic | $C_4\ H_4\ O_4$ | 1062 | 243° |
| Butyric | $C_8\ H_8\ O_4$ | 973 | 314 |
| Carbolic | $C_{12}\ H_6\ O_2$ | 1065 | 370 |
| Cresylic | $C_{14}\ H_8\ O_2$ | — | 397 |
| Phlorylic | $C_{16}\ H_{10}\ O_2$ | — | 424 |
| Rosolic | $C_{24}\ H_{12}\ O_6$ | — | — |
| Brunolic | ? | — | — |

*Neutral Bodies of Coal Tar.*

| | | | |
|---|---|---|---|
| Aliacious oils | ? | ? | ? |
| Benzole | $C_{12}\ H_6$ | 850 | 177 |
| Toluole | $C_{14}\ H_8$ | 870 | 230 |
| Xylole | $C_{16}\ H_{10}$ | 867 | 264 |
| Cumole | $C_{18}\ H_{12}$ | 870 | 299 |
| Cymole | $C_{20}\ H_{14}$ | 861 | 341 |
| Naphthaline | $C_{20}\ H_8$ | 1153 | 428 |
| Anthracine | $C_{28}\ H_{10}$ | 1147 | 572 |
| Pyrene | $C_{30}\ H_{12}$ | — | ? |
| Chrysene | $C_{24}\ H_8$ | — | ? |

*Basic or Alkaline Bodies of Coal Tar.*

| | | | |
|---|---|---|---|
| Pyridine | $C_{10}\ H_5\ N$ | 986 | 242 |
| Pyrrol | $C_8\ H_5\ N$ | 1077 | 271 |
| Picoline | $C_{12}\ H_7\ N$ | 961 | 273 |
| Lutidine | $C_{14}\ H_9\ N$ | 946 | 310 |
| Collidine | $C_{16}\ H_{11}\ N$ | 937 | 354 |
| Parvoline | $C_{18}\ H_{13}\ N$ | — | 370 |
| Aniline | $C_{12}\ H_7\ N$ | 1080 | 360 |
| Toluidine | $C_{14}\ H_9\ N$ | — | 388 |
| Xylidine | $C_{16}\ H_{11}\ N$ | — | 418 |
| Cumidine | $C_{18}\ H_{13}\ N$ | 952 | 437 |
| Cymidine | $C_{20}\ H_{15}\ N$ | — | 482 |
| Chinoline | $C_{18}\ H_7\ N$ | 1081 | 462 |
| Lepidine | $C_{20}\ H_9\ N$ | 1072 | 510 |
| Cryptidine | $C_{22}\ H_{11}\ N$ | — | 525 |

The general properties of coal tar, as well as the proportions of its several constituents, vary with the quality of the coal used, and with the temperature at which it is distilled or carbonized. The tar which is produced from common gas coals at a rather high temperature is always heavier than water (sp. gr. 1120 to 1150). It dries freely in the air, and its hydrocarbons are so rich in carbon that the tar cannot be burnt in an ordinary lamp. But the tar which is produced from cannel coals at lower temperatures is lighter than water, and does not readily dry when it is exposed to the air. Besides which, its hydrocarbons are comparatively poor in carbon, and may be burnt in lamps. There is almost every variety of coal tar from these two extremes, but the tars of commerce are chiefly of three kinds—viz., the rich cannel coal tar of Scotland; the tar which is produced from common coal in country gas-works, where the temperatures are generally low; and the still heavier tar of the London gas-works, which is produced at excessively high temperatures. The yield of tar per ton of coals is from 9 to 15 gallons—the latter being the average at country works; and the former, or from that to 10 gallons, is the yield in London, where the tar is undoubtedly affected by the high temperature of the retorts, for it is not only small in quantity, but it is deficient of naphtha, and contains more pitch than country tar; besides which, the dead oil from it is always overloaded with naphthaline.

In London the distillation of coal tar is always effected in stills, which are placed over a fire, and the products are collected at different stages of the distillation. Up to a temperature of from 160° to 190° Fahr. little or nothing flows over, but at that temperature ammoniacal liquor, with *crude naphtha* of a gravity of 850, begins to distil. These continue to flow until the thermometer rises to from 310° to 340°, when a heavier naphtha of a gravity of about 920 is carried over. This is called *light oil*, and it is collected separately until the temperature rises to from 370° to 400°, and then the oil begins to have the gravity of water; after that, and up to the temperature of from 690° to 700°, the oil which is collected is heavier than water, and is therefore called *heavy oil* or *dead oil*—the last runnings having a gravity of 1060, or thereabouts. If a soft pitch is wanted the process of distillation is stopped at this stage, but if a harder pitch is required it is pushed a little further, and the *green oil* which flows over is rich in neutral oils, which are well suited for making railway grease.

A still containing 2500 gallons of coal tar will in this way yield about the following proportions of the several products:—

| | | | | |
|---|---|---|---|---|
| Ammoniacal liquor from | 50 to 70 gals. | (average) | 60 gals. |
| Crude naphtha | 30 „ 50 „ | „ | 40 „ |
| Light oil | 12 „ 35 „ | „ | 30 „ |
| Creosote or dead oil | 689 „ 740 „ | „ | 720 „ |
| Pitch | 8 „ 10 tons | „ | 9 tons. |

Each of these products has its commercial value, the naphtha and light oil being used for the production of benzole and toluole of commerce—naphthas which are largely in demand for the manufacture of coal-tar colours.

Formerly the greatest value was attached to the naphtha or benzole which had a low boiling-point, and the contracts, especially with the French, were for a benzole or naphtha which yielded 90 per cent. of volatile oil at a temperature not exceeding 212°, and I have examined thousands of gallons of this quality for the French market. Even at the present time there is a demand for this, which is called 90 per cent. benzole, for making certain aniline reds; and to obtain it the crude naphtha, or the first runnings from the tar, were distilled alone. At present, however, there being a demand for a less volatile oil, the practice is to mix together the crude naphtha and the light oil, and to subject them to fractional distillation, thus:—Steam is blown into them at a pressure of from 20 to 30 lbs. on the inch, and the naphtha which comes over with the steam is called *once run naphtha*. This is purified by shaking it with strong sulphuric acid (sp. gr. 1845), using the acid in small proportions at a time, for fear of injuring the naphtha, and washing with water between each operation. In this manner, after using about 5 per cent. of acid (or ½ lb. to each gallon of naphtha), the brown colouring matter of the naphtha and all basic compounds are either destroyed or removed, and the brown naphtha, after being well washed with water, is again distilled by blowing high-pressure steam into it, and the products are collected at three stages; that which comes over first is called *crude benzole of 80 per cent. strength*, the second runnings are a naphtha containing 50 *per cent. of benzole*, and the third is a naphtha which is used for solvent purposes. With the view of strengthening the 50 per cent. benzole, and making it 80 per cent., it is redistilled from a vessel with a steam jacket, whereby the temperature can be regulated. That which flows over at a temperature up to 210° is set aside as 80 *per cent. benzole*; that which distils between 210° and 260° is called 30 *per cent. naphtha;* and the residuum, on being treated with high-pressure steam, yields *solvent naphtha*. Once more the 50 per cent. naphtha, or that which has flowed over at from 210° to 260°, is distilled with a dry steam heat, and when the thermometer has risen to 106° there is obtained a little more 80 per cent. benzole; after which, and up to 234°, there flows over what is called 40 per cent. naphtha, and from 234° to 260° a little of the 50 per cent. Steam is then blown into it, and it yields a little more of the solvent naphtha.

In this way, by a series of fractional distillations, the washed naphtha is made to yield at each successive operation a quantity of 80 and 40 per cent. naphtha. All the 80 per cents. are then mixed together, and are once more distilled by a dry steam heat. The naphtha which flows over at a temperature up to 204° is called 90 per cent. benzole; that which flows between 204° and 210° is called 80 per cent. benzole, and is again fractionally distilled up to 204°; while the residue, on being treated with high-pressure steam, yields a quantity of 40 per cent. naphtha.

Five separate products are thus obtained—namely, 90 per cent. benzole, 40 per cent. benzole, solvent naphtha, the last runnings of the first operation, and the residuum of each distillation. Operating in this manner with a charge of 1587 gallons of crude naphtha and light oil, there is first obtained 897 gallons of once run naphtha and 56 gallons of the last runnings, the remainder (634 gallons) being a residuum of no value except for mixture with dead oil; and the 897 gallons of once run naphtha yields, after it has been purified with sulphuric acid, 301 gallons of 90 per cent. benzole, 195 gallons of 40 per cent., 237 gallons of solvent naphtha, 12 gallons of last runnings, and 152 gallons of residuum.

The 40 per cent. benzole contains also 50 per cent. of volatile oil, chiefly toluole, which distils over between 212° and 248°. This is the oil which is preferred at the present time for the manufacture of coal-tar colours. The several products which are thus obtained in the distillation of coal tar are upon the table before you, and, roughly speaking, the proportions per 10,000 gallons of crude tar and their commercial values are as follows:—

| | | | |
|---|---|---|---|
| 40 per cent. benzole | 34·4 gals., | worth 2 s. 4d. | per gal. |
| 90 per cent. „ | 53·1 „ | „ 2s. 0d. | „ |
| Solvent naphtha | 41·8 „ | „ 1s. 9d. to 2s. | „ |
| Last runnings | 12·0 „ | „ 0s. 9d. | „ |
| Dead oil | 3018·7 „ | „ 0s. 1d. | „ |
| Pitch | 36 tons | „ 45s. 0d. | per ton. |

Before rectification the crude naphtha is worth about 1s. per gallon, and the light oil about 6d., the two together fetching 9d. or 10d. a gallon; and once run naphtha is worth 1s. 6d. a gallon. Two samples of this oil from different distillers yielded by fractional distillation the following per centage proportions of oil at different temperatures:—

| | Sample 1. | Sample 2. |
|---|---|---|
| Up to 212° Fahr. | 15·0 | 17·5 |
| From 212° to 248° | 44·0 | 42·0 |
| „ 248° to 264° | 8·0 | 8·5 |
| „ 264° to 300° | 13 0 | 13·0 |
| „ 300° to 320° | 5·5 | 4·5 |
| Residuum | 14·5 | 14·5 |
| | 100·0 | 100·0 |

The samples, therefore, in commerce from good makers may be regarded as of pretty uniform quality.

In Scotland the method of distilling coal tar is a little different from what it is in England, and this arises from the circumstance that the Scotch cannels yield a tar which is so rich in the volatile naphthas that it is not altogether safe to distil the tar from a still with a naked fire. The tar, therefore, is first submitted to the action of high-pressure steam, which is blown into it until the more volatile products are passed off. In this way from 7 to 13 per cent. of *crude or rough naphtha* is obtained with a gravity of about 930. The residuum is called boiled tar, and is distilled with a naked fire. It thus yields from 6 to 7½ per cent. of a *light oil* called *pitch oil* or *torch oil*, which has a specific gravity of from 973 to 976. The next runnings, which amount to from 27 to 30 per cent. of the boiled tar, are generally heavier than water, and are called *heavy pitch oil*, and they constitute the great bulk of the product.

The several products of coal tar are thus used in the arts:—

*Coal tar* is itself employed as a rough varnish for iron, and in Scotland the *boiled tar* is extensively used for covering woodwork, &c.

*Light oil and crude naphtha* are either redistilled for procuring benzole and toluole, as I have already explained, or they are employed for making common black varnish, or for burning in naphtha lamps. In this country they are for the most part distilled, but in Scotland they are largely used in a lamp called the *foundry lamp*. It is an enlarged form of a lamp which was patented many years ago by Mr. Beale, and it consists of a chamber supplied with naphtha, and having a nozzle or jet for directing a blast of air through it. The chamber is covered with a bell with a large hole in the top of it. When the naphtha is lighted and the bell put upon it, the blast of air forces the vapour of the burning naphtha through the hole in the top of the bell, and thus produces an enormously large volume of flame. The light is equal to at least a dozen gas-jets, and the cost of it is said to be a penny a night. It is very generally used in the foundries, the ship yards, and other large workshops of Scotland.

*Solvent naphtha* is a colourless spirit which is chiefly employed for dissolving india-rubber for waterproofing, and resins or pitch for varnishes.

The *last runnings* are also used for varnishes, for making a superior lamp black called *spirit black*, and for burning in Holliday's lamp, which is the common naphtha lamp of the streets. It is an ingenious contrivance for converting the naphtha into vapour by means of a mass of heated metal and spreading it out in a star-like form.

I have already alluded to the use of coal naphtha as a means of increasing the illuminating power of common 12 or 14 candle gas, and have shown that with a moderately good naphtha, which yields about seven grains of vapour to every cubic foot of gas, the illuminating power may be increased about 60 per cent. Considering that naphtha is now becoming a drug in the market, from the waning of fashion in respect of coal-tar colours, it may be worth while to encourage its use as a naphthalizer, rather than to yield to the public clamour for cannel gas. I have long thought that gas, as well as water, should be dealt with at the consumers houses, when in either case it is required to be of unusual quality.

*The creosote, or dead oil of coal tar*, is used almost entirely for the preservation of timber, and at the present moment, in the stagnant condition of railway business, it is almost unsaleable. I apprehend, however, that it is valuable as a fuel, and that it will ere long be used in steam furnaces. Already there are several patents for its application in this manner, and experiments are now being conducted at Woolwich with the view of ascertaining its practical and economical capabilities. The contrivances which appear to offer the largest prospects of success are those which deliver the oil into the furnace in the form of a spray or vapour, by means of a jet of steam or blast of hot air; and it is said that the heating power of the oil is from 2½ to 3 times that of a similar weight of coal.

In applying the oil to the preservation of timber it is necessary that it should be forced deeply into the tissue of the wood. The method employed by the best operators is to place the timber in large wrought-iron cylinders, and then to exhaust it of air and moisture as completely as possible by creating a vacuum. After a time the dead oil, heated to a temperature of 120° Fahr., and thus made as fluid as possible, is let into the cylinder. Pressure is then put upon it until the oil is forced into the wood with a power 150 lbs. upon the inch. In about three hours the wood absorbs the prescribed amount of creosote, which, with the best houses, is never less than from 30 lbs. to 50 lbs. of creosote to a load of 50 cubic feet of timber; every cubic foot of timber has, therefore, taken up from 6 lbs. to 10 lbs. of oil.

The preservative power of the dead oil is partly due to the antiseptic properties of the creosote, and partly to its filling up the pores of the wood with an oil which gradually resinifies and excludes air and moisture. Different views are entertained of the quality of creosote which is best suited for this purpose. In the contracts which I have prepared for the Indian railway works, I have prescribed that the creosote should have the following properties:—"It should have a density between 1045 and 1055; it should not deposit any crystalline matter at a temperature of 40° Fahr.; it should yield not less than 5 per cent. of crude carbolic acid to a solution of caustic potash of the density of 1070 (14° Twaddle): and it should furnish 90 per cent. of liquid oil when distilled to the temperature of 600° Fahr." The contracts, which I have lately seen, for the Dutch Government, prescribe that the creosote shall be clear, and shall not deposit more than 40 per cent. of naphthaline when cooled to the temperature of 32°, and kept at that temperature for 24 hours. Here are specimens of creosote from country tar which fully realizes those properties; but this sample from London tar is almost solid at 32°.

Another use to which dead oil has lately been put is the preparation of a dip for washing sheep. It was patented by Mr. M'Dougall in 1860, and is made by heating together two parts by weight of dead oil with one of a solution of caustic soda of 50° Twaddle (sp. gr. 1250), which contains about 15 per cent. of soda; and to this is added one part of tallow, fat, or other saponifiable substance. The mixture which is thus obtained has the appearance of a very dark soft soap, and it is either smeared upon the skin of the animal, or dissolved in water and used as a wash.

The *greasy matter, or green oil*, which follows the dead oil in the distillation of coal tar, is used for making railway grease, with resin, oil, &c.; and the pitch which is the residual product of the distillation is largely employed for all sorts of purposes.

Looking, therefore, at the compositions of the principal products of coal tar distillation, it may be said that the *crude naphtha* contains certain allianceous oils, with benzole, toluole, xylole, cumole, and a little cymole, besides the more volatile basic compounds, as pyridine, picoline, lutidine, collidine, and a little aniline, with from 2 to 3 per cent. of carbolic acid and a little naphthaline.

*Light oil* contains cumole, cymole, and the other less volatile hydrocarbons, with a large amount of naphthaline, and the denser alkaloids, as collidine, aniline, toluidine, and even a little chinoline; besides which it contains from 10 to 20 per cent. of carbolic and cresylic acids.

*Heavy oil* consists chiefly of hydrocarbons which have not been well studied, and the bases which have a high boiling-point, as chinoline, lepidine, and cryptidine, with small quantities of cumidine and cymidine, and from 7 to 10 per cent. of carbolic and cresylic acids.

*Carbolic acid* ($C_{12} H_6 O_2$), or as it is sometimes called *phenic acid*, is largely in demand for making dyes and for disinfecting purposes, and it is most profitably extracted from the light oil before it is distilled for benzole, &c. The naphtha which flows over between 300° and 400° Fahr., and which has a gravity below 900, is best suited for the preparation of carbolic acid; for although there is much acid in the heavier oils, yet they are so nearly of the same gravity as the alkaline solution used in extracting it that there is great difficulty in separating them. The light oil is well shaken with about one-third of its bulk of a solution of caustic soda of from 14° to 16° Twaddle (1·07 to 1·08 sp. gr.) and containing from 5 to 7 per cent. of alkali. After standing for some time the oil separates, and the alkaline liquor may be drawn off by means of a syphon. This is to be neutralized with sulphuric or muriatic acid, and then the carbolic acid floats as a dark brown oil. This is the crude acid of commerce, and when purified by means of sulphuric acid and careful distillation from chloride of calcium, it forms the camphor-like substance which you here see. It has a peculiar creosote-like smell, and when largely diluted with water, even to the extent of 1 part in 10,000, it has a sweet taste. It is a very powerful caustic, turning the skin white and quickly raising a painless blister. The specific gravity of the pure acid is 1·065. It melts at from 95° to 98° Fahr., but the merest trace of water will lower its melting or congealing point, so that this is the test of the quality of the acid. It boils at 369° or 370° Fahr., and its vapour burns with a sooty flame. If it be passed through a red-hot tube it is decomposed, forming naphthaline and other hydrocarbons; and if it be heated for some time with ammonia in a closed tube, at a temperature of from 400° to 500° Fahr., it produces aniline and water, thus:—

$$\underbrace{C_{12} H_6 O_2}_{\text{Carbolic acid.}} + NH_3 = \underbrace{C_{12} H_7 N}_{\text{Aniline.}} + 2\,HO$$

It combines with alkalies to form salts, but the combination is very feeble, for the acid is set free by heat and even by the carbonic acid of the atmosphere, so that the common preparation of it, carbolate of lime, slowly evolves carbolic acid when it is exposed to the air.

The acid is a very powerful antiseptic and disinfectant. It is especially destructive of the lower forms of organic life, and hence, perhaps, its value as a disinfectant. Several varieties of the acid are now prepared and sold for general and medical purposes, and the experience of the last few years has proved it to be an important hygienic agent. Its use in the preparation of dyes will be explained directly.

The other acids of coal tar, as *cresylic* ($C_{14} H_8 O_2$), *phlorylic* ($C_{16} H_{10} O_2$), *rosolic* ($C_{21} H_{12} O_3$), may be obtained by the use of a stronger alkaline solution, as recommended by Laurent. A saturated solution of potash, added to the mixed light oil and heavy naphtha, and then treated with a little powdered caustic potash, will produce a magma from which the unattacked liquid oil may be separated. By dissolving it in a small quantity of water and allowing it to stand, it separates into two layers—an upper oily layer which is of no use, and a lower layer which contains the tar acids. When this is neutralized with muriatic acid, the crude acids float as an oily layer, and may be separated from each other by fractional distillation.

### IV.—Spent Oxide of Iron.

This is the next substance in the order of the purification of coal gas. In its fresh state the hydrated peroxide of iron freely absorbs the sulphuretted hydrogen of foul gas, forming the black sulphide of iron. On exposure to the air the iron again absorbs oxygen, and become revived—the sulphur which it had before taken in as sulphuretted hydrogen being set free among the particles of the oxide. In this manner, by a succession of foulings and revivifications, the oxide becomes so charged with sulphur as to be unfit for use. It then contains from 35 to 57 per cent. of sulphur, the average being about 42 per cent.; and although it is useless at the gas-works, it is of some value in the production of oil of vitriol. Special furnaces, however, are necessary for its combustion, for as it contains about 20 per cent. of sawdust it is not capable of being used in the ordinary sulphur furnaces. At Messrs. Lawes and Messrs. Hills, where I have seen the spent oxide largely used for making sulphuric acid, the furnaces are constructed with very long flues, for the purpose of completely burning the organic vapour before it enters the vitriol chamber. Each furnace is about 12 feet long and 18 inches square, with a floor of fire-brick, upon which the oxide burns. It takes about 2½ cwts. of oxide at a charge, and it burns continuously for twelve hours. The air is admitted by a sliding door in front, and the gaseous products are conveyed from the furnaces, which are placed side by side, and in three tiers over each other, to a common flue at the back, and this is extended backwards and forwards, below and above, so as to prolong the combustion to the greatest extent before the vapours enter the vitriol chamber, for if the combustion is not complete there is a considerable waste of nitre; as it is, indeed, the quantity of nitre used for the oxidation of the sulphurous acid is always about half as much more as is required with native sulphur or pyrites. I think the process might be very considerably improved by continuous instead of intermittent burning, and there is no reason why the use of sawdust may not be abandoned altogether, and spent oxide employed in its place.

### V.—Spent or Refuse Lime.

This is generally a very profitless material—in fact, the blue billy from the wet-lime purifiers is incapable of any sort of application but that of luting. Dry lime, however, is not so unmanageable a product, for if it is treated properly it need not occasion offence; and when it is well weathered it is of some value to the farmer. Professor Voelcker has inquired very fully into this matter, and he states that it is useful to certain soils on the following account:—

1. It improves the texture of stiff clay soils by lightening them, and of light sandy soils by giving them solidity,

2. It neutralizes the acidity of some soils, and breaks up the organic matter of soils which are too rich in humus, making them more fit for the sustenance of plants.

3. It acts on the granitic constituents of a soil, and sets free the alkalies, thereby making the mineral elements of it available as food for the plant.

4. It supplies food to the plant in the form of sulphate of lime, which is especially useful to the leguminosæ.

And he concludes that well weathered gas lime, judiciously applied to a proper soil, is most useful to many plants, as clover, sainfoin, lucerne, peas, beans, vetches, and turnips; and that it is a good fertilizer for permanent pasture, especially if the land is deficient of lime. On natural grasses the best farmyard manure often produces but little improvement until a dressing of lime, marl, or gas lime has been applied to it: the latter, more

particularly, destroys the coarser grasses, and favours the growth of a sweeter and more nutritious herbage. It also destroys moss, heath, feather-grass, and other plants which are characteristic of peaty land. It is, therefore, especially suited for the improvement of such land; and so it is for land which is deficient of lime, and which causes turnips to become warty, and to be affected with the disease called "fingers and toes." For this it has been found a complete remedy. It may be applied in quantities of from one to two tons an acre, and even more where lands are very heavy, or are very peaty; and the best time to apply it is in the autumn, when vegetation is dormant, so that it can not only weather before the spring returns, but also act on the land during the whole of the winter.

One especial precaution is that the lime should never be used in its fresh state, when it contains sulphide and sulphite calcium in such proportions as to be injurious to plants. The more it is oxidized the better, and, therefore, when it is drawn from the purifiers it should be covered over with old material, so as to prevent smell, and kept until it has lost its activity. The fresh lime contains from 15 to 25 per cent. of quicklime, with a large proportion of sulphide, carbonate, and sulphocyanide of calcium; and even after six or eight months it may still contain a notable proportion of quicklime, with from 20 to 30 per cent. of sulphate of lime, a like proportion of sulphite of calcium, and still more of carbonate, in which condition it is not injurious to plants.

In many places farmers are glad to have the material, and will give as much as 2s. a load for it, although the common price is about 1s. a load.

VI.—Acid and other Absorbents of Ammonia.

At the end of all the purifiers there may be placed the material which has been patented by Messrs. Sugden and Maryatt. It is made by moistening sawdust with sulphuric acid slightly diluted with water, and heating it in a retort. The woody matter is in this way charred by the acid, and contains from 30 to 45 per cent. of free sulphuric acid. When it is exhausted by being charged with ammonia, it contains from 40 to 60 per cent. of the salt, which is easily washed out of it, leaving the charred sawdust ready for another charge of acid. The material, with the sulphate of ammonia in it, is fit for conversion into manure, and is worth about £5 or £6 per ton. Another absorbent of a like nature is that used by Mr. Croll. It is made from the spent chloride of manganese from the bleaching-works, by adding to it chalk and sawdust, and, when saturated with ammonia, it contains from 34 to 40 per cent. of muriate of ammonia, which is easily obtained from it either by washing or subliming.

These are the several waste products of the manufacture of gas, and it will be seen that, in the aggregate, their value is not inconsiderable provided they are utilized to the fullest extent.

Coal-Tar Colours.

And now I will make a few remarks on the processes which are followed for the production of coal-tar colours. Most of them are derived from the naphtha which is sold as 40 per cent. benzole, which is a mixture of benzole and toluole with a little xylole. The first step of the process is to convert the constituents of this naphtha into the corresponding nitro-compounds, by carefully mixing it with fuming nitric acid or with a mixture of two parts of common nitric acid and one sulphuric. The reaction is very violent if the temperature is not controlled; but, with proper management, the three hydrocarbons lose each an equivalent of hydrogen to a like proportion of oxygen in the nitric acid, and gain the residual peroxide of nitrogen. Thus—

$$\underbrace{C_{12}\,H_6}_{\text{Benzole.}} + H\,NO_6 = \underbrace{C_{12}\,H_5\,NO_4}_{\text{Nitrobenzole.}} + 2\,HO$$

$$\underbrace{C_{14}\,H_8}_{\text{Toluole.}} + H\,NO_6 = \underbrace{C_{14}\,H_7\,NO_4}_{\text{Nitrotoluole.}} + 2\,HO$$

$$\underbrace{C_{16}\,H_{10}}_{\text{Xylole.}} + H\,NO_6 = \underbrace{C_{16}\,H_9\,NO_4}_{\text{Nitroxylole.}} + 2\,HO$$

These three nitro-compounds constitute the dark amber-coloured, oily liquid which floats upon the acid; and when it is separated from the acid and washed with water, and then with a weak solution of carbonate of soda, it constitutes the crude nitrobenzole which is used for the manufacture of aniline colours.

It has a strong odour of bitter almonds, is heavier than water, and is very soluble in alcohol and ether. If this crude nitrobenzole be submitted to the action of a reducing agent, each of the nitro-compounds will lose its four equivalents of oxygen, and gain two of hydrogen, and be thereby converted into a corresponding alkaloid, thus—

$$\underbrace{C_{12}\,H_5\,NO_4}_{\text{Nitrobenzole.}} + 6\,H = \underbrace{C_{12}\,H_7\,N}_{\text{Aniline.}} + 4\,HO$$

$$\underbrace{C_{14}\,H_7\,NO_4}_{\text{Nitrotoluole.}} + 6\,H = \underbrace{C_{14}\,H_9\,N}_{\text{Toluidine.}} + 4\,HO$$

$$\underbrace{C_{16}\,H_9\,NO_4}_{\text{Nitroxylole.}} + 6\,H = \underbrace{C_{16}\,H_{11}\,N}_{\text{Xylidine.}} + 4\,HO$$

This process of reduction may be effected by sulphide of ammonium (Zinin's method), or by the nascent hydrogen evolved when zinc is treated with dilute sulphuric acid (Hofmann's method), or by acting on the nitro compounds with iron and acetic acid (Bechamps process). I show you here an experimental illustration of each of these processes, and you will observe that for lecture experiment the process of Hofmann is the most striking, but in practice the method of Bechamps is the most economical.

One hundred parts of the crude nitrobenzole is mixed with nearly its own weight of strong acetic acid, and to this is added little by little about 150 parts of iron turnings. The mixture is generally made in an iron retort, and after being well stirred it becomes hot, and soon forms a pasty mass of oxide of iron with acetate of aniline and the other bases. The reactions are somewhat intricate, but they may be practically expressed thus—

$$\underbrace{C_{12}\,H_5\,NO_4}_{\text{Nitrobenzole.}} + 4\,Fe + 2\,HO = \underbrace{C_{12}\,H_7\,N}_{\text{Aniline.}} + 2\,(Fe_2\,O_3)$$

And the same for the other nitro-compounds, so that theoretically the acetic acid should act indefinitely.

The mixture is then submitted to heat until the retort is nearly red hot, by which means impure aniline, &c., distils over, and when this is treated with a slight excess of lime or soda, and again distilled, it yields the crude aniline of commerce. The best product is obtained when the distillation is going on between the temperatures of 340° and 380°, for as the temperature rises to 626° two new alkaloids are produced, which Hofmann has named *paraniline* ($C_{24}H_{14}N_2$) and *æthylamine* ($C_{24}H_{11}N$).

Other processes have been suggested for the production of aniline and its homologues from the nitro-compounds, thus Kremer has recommended the use of finely powdered zinc; Wohler, an alkaline solution of arsenious acid; Wagner, the ammoniacal solution of suboxide of copper; and Vohl, an alkaline solution of grape sugar, but none of these methods have taken the place of Bechamps.

The crude aniline of commerce, which is a mixture of aniline and toluidine, is a more or less deeply coloured liquid of an amber tint; it is heavier than water, and it acquires a blue or red colour by various oxidizing agents. A solution of chloride of lime turns it, as we see, of a bluish-purple colour. It was this reaction which suggested the name of *kyanol*—blue oil. Acidulated with a mixture of equal parts of water and strong sulphuric acid, and treated with peroxide of manganese or peroxide of lead, it produces, as you observe, a rich blue. Chromic acid makes it, as you may see, of a green, a blue, or a black colour, according to the degree of oxidation; but the most remarkable experiment of all is the coloration of the aniline when it is acidulated with dilute sulphuric acid and submitted to the action of the galvanic battery. At the platinum pole, where oxygen is evolved, it instantly becomes bronze-green, then blue, then violet, and finally red; showing that the coloration of the alkaloid is due to the nascent oxygen, and that the tint corresponds to the degree of oxidation.

The crude aniline dissolves to some extent in water, but it is more freely soluble in alcohol and ether. It readily combines with acids, and forms crystalline compounds; hence it was called *crystalline* by Unverdorben, its discoverer. These salts become coloured on exposure to the air.

The production of colours from this liquid was the remarkable feature of the Exhibition of 1862. It dates from the year 1856, when Mr. Perkin discovered and patented the process for making a rich violet from aniline by means of bichromate of potash; but it is right to say that several chemists had long before noticed the fact that the salts of aniline were capable of producing rich colours. Runge, in 1835, obtained a violet blue by acting on one of the oily constituents of coal tar with chloride of lime. Five years afterwards Fritzsche observed the blue coloration of aniline with chromic acid, and the like thing was described by Beisenhirtz; but none of these reactions commanded attention until the year 1859, when Messrs. Guinon, Marnas, and Bonnet, of Lyons, introduced a new fast purple under the name of *French purple*, which they obtained from Orchil, and which became a favourite and fashionable colour. The *mauve* of Mr. Perkin, which had been for three years before the public, was so much like it, that it rose suddenly into public favour. The year after, in 1859, M. Verguin, of the firm of Renaud Brothers, of Lyons, obtained a brilliant red from the same base, and it was patented by them under the name of *fuchsine*. These two results commanded so much attention that the scientific and technical world entered very earnestly into the investigation with the view of discovering new processes of manufacture; and at the present time we have the means of making almost every variety of tint from coal-tar products. Most of these dyes are called aniline colours, but in truth they are produced from toluidine as well as aniline, and, as we shall see hereafter, they are obtained by processes of oxidation and substitution. They are generally classified under the heads of violets, reds, blues, greens, blacks, yellows, &c

*Violets.*

These have received a variety of fanciful names, as *mauve*, *violine*, *rosolane*, *tyraline*, *indisine*, *harmaline*, *imperial violet*, *regina purple*, &c., &c.

The first of them was obtained in 1856 by Mr. Perkin, whose patent is dated the 26th of August of that year. His process is to add equivalent proportions of diluted solutions of a salt of aniline (generally the sulphate) and bichromate of potash. A good proportion is 2 parts by weight of aniline, 2 of bichromate of potash, and 1 of sulphuric acid of English commerce. The aniline and sulphuric acid are first mixed and then dissolved in water. To this solution is added the bichromate of potash, also previously dissolved in water, and after being well stirred they are allowed to remain quiet for 10 or 12 hours, when a dark-coloured sediment appears. This is to be collected upon a filter and well washed with cold water. It is then dried and treated with colourless coal-tar naphtha until all brown tarry and resinous matter is dissolved away. After this it is again dried and boiled in successive portions of alcohol or methylated spirit until the whole of the violet colouring matter is dissolved out. The spirit solutions are then distilled in order that the spirit may be recovered, and the residue is mauve. It amounts to only about 4 or 5 per cent. in weight of the aniline used, but its tinctorial power is very great. In this condition it is not absolutely pure, although it is sufficiently so for common purposes. To purify it, it must be boiled in a large quantity of water, and the solution treated with an alkali. The colouring matter which precipitates is to be collected upon a filter, washed with water until all trace of alkali is removed, and then dissolved in spirit. If the spirituous solution be evaporated to dryness, the pure colouring matter remains as a beautiful bronze-like substance. It is hardly at all soluble in water, ether, or coal-tar naphtha; but it freely dissolves in spirit and in weak acids, especially acetic. Concentrated sulphuric acid dissolves it without decomposing it, and forms a dirty green solution which becomes of a beautiful blue colour with a little water, and a violet or purple with a good deal. It is, therefore, a very permanent body, although it will not resist the action of chlorine or nitric acid. Reducing agents, as sulphide of ammonium or protosulphate of iron, change it to a brown-coloured solution, which reacquires its violet tint on exposure to the air. Like most of the aniline dyes it forms a very insoluble coloured precipitate with tannin.

Other processes have been patented for making this colour; thus, Bolley, in 1858, Beale and Kirkham, in 1859, and Depouilly and Lauth, in 1860, patented the use of chloride of lime with a salt of aniline. These solutions, when used in proper proportions, produce an insoluble purple precipitate, which is the mauve of Perkin. It is purified by washing it with water slightly acidulated with sulphuric acid, then dissolving it in concentrated sulphuric acid, reprecipitating with water, washing it with water upon a filter, and lastly dissolving in spirit. In 1859, Mr. Kay patented a process for obtaining it by adding peroxide of manganese to a strong solution of sulphate of aniline, and keeping the mixture for some hours at the temperature of boiling water. The purple solution thus obtained is to be filtered and precipitated by adding ammonia until the acid is neutralized; and the precipitate, when collected upon a filter, washed with water, and then dissolved in spirit, forms the violet-coloured dye called *harmaline*. In the same year Mr. D. Price procured a patent for manufacturing the colour by means of peroxide of lead instead of peroxide of manganese, and Mr. Greville Williams obtained a patent for permanganate of potash. The year after (1860) there were several patents for it, as Mr. Stark's, with ferricyanide of potassium, and Messrs. Dale and Caro's with perchloride of copper and chloride of sodium.

In the year 1861, M. Adam Girard observed that a purple colour could be obtained from aniline red by mixing it with its own weight of aniline and

exposing it for several hours to a temperature of 350° Fahr., which is a little short of the boiling-point of aniline. The mixtures employed were equal parts of dry muriate of roseaniline and aniline, and the product, which is a reduced condition of aniline red, is washed with water slightly acidulated with muriatic acid until all the unacted on aniline and aniline red are removed and the pure purple remains. This is dissolved in spirit or acetic acid, and forms the dye called *Imperial purple*. In the year following (1862), Mr. Nicolson obtained his patent for procuring the same colour by merely heating Magenta or aniline red to a temperature of from 390° to 420° Fahr. The substance first melts, and, after evolving ammonia, is changed into the purple which he named *Regina purple*.

*Aniline Reds,*

called *fuchsine*, *roseine*, *azaleine*, *roseaniline*, *Magenta*, *Solferino*, and other fanciful names which are conspicuous in the American section of the Paris Exhibition of this year. This colour was obtained by Dr. Hofmann as far back as the year 1843, when he was experimenting on aniline with fuming nitric acid; and 15 years later (in 1858) he again obtained it, when he was studying the reactions of bichloride of carbon on aniline. He found, indeed, that when 3 parts of aniline were heated with 1 part of bichloride of carbon for some time, a resinous mass was produced which furnished to alcohol a rich crimson colour. This was aniline red; but, as he was studying the reactions for other purposes than the formation of coloured products, he merely noticed the fact, and put it upon record. A year after Messrs. Verguin and Renaud Brothers, of Lyons, discovered and patented their process for making *fuchsine*, or aniline red, from aniline, by means of bichloride of tin; and thus a practical value was given to the scientific researches of Dr. Hofmann. Fuchsine is obtained by heating together 10 parts of aniline and 6 of anhydrous bichloride of tin in a glazen iron vessel for 15 or 20 minutes. The temperature should be about that of the boiling-point of the mixture (392° Fahr.). At first the mixture becomes yellow, then gradually more and more red, until the liquid mass looks black. When this occurs it is allowed to cool, and the mass is treated with a large quantity of boiling water, which acquires a rich crimson colour. This is the dye, and it may be used at once, or purified by adding to it a quantity of common salt, in which solution the dye is insoluble. The precipitated colouring matter is allowed to subside, and, after being collected upon a filter, it is dissolved in spirit, or acetic acid, and so forms the red dye. The process patented by Mr. David Price, in the year following (1859), was to act upon a solution of sulphate of aniline with peroxide of lead, by boiling them together in the proportion of one equivalent of the former to two of the latter, until the solution acquires a deep red colour. This is filtered; and, after being concentrated by evaporation, it is again filtered, to separate a resinous substance which forms in it. An alkali is then added to neutralize the acid, and the colouring matter is precipitated as a dirty brown powder. When this is collected upon a filter, washed with water, and dissolved in spirit or acetic acid, it forms a beautiful red dye, which is fit for use. Messrs. Simpson, Maule, and Nicholson, used this process very largely until the beginning of the year 1860, when Dr. Medlock committed to them his patent for making aniline red by means of arsenic acid. The process now followed is to mix together a highly concentrated solution of arsenic acid with aniline, using the latter a little in excess; a good proportion is 20 parts by weight of syrupy arsenic acid, containing 76 per cent. of the solid acid and 12 of commercial aniline. In this manner a pasty mass of arseniate of aniline is formed, and, when this is heated for some time at a temperature of about 300° Fahr., it intumesces, and at last forms a dark-coloured liquid, which, on cooling, sets into a resinous solid, with a bronze-like lustre. The crude colouring matter thus obtained is very soluble in spirit or water, and may be at once used for dying purposes, but it is better to purify it by adding a slight excess of slaked lime to the aqueous solution, and so precipitating the colouring matter with the insoluble arsenical salts of lime. The mixed precipitates are collected upon a filter, and the colouring matter dissolved out with acetic or tartaric acid. Another and better method of purification is to dissolve the crude mass in dilute muriatic acid; then to filter, and to precipitate by adding a slight excess of alkali (carbonate of soda). The colour thus set free is to be collected upon a filter washed with water, and then dissolved in spirit and acetic acid.

Another variety of aniline red, the nitrate of roseaniline, or *azaleine*, has been extensively manufactured in England by the process of Mr. Perkin, and in France by that of M. Gerber Keller. Mr. Perkin heats a mixture of aniline, or its homologues, with dry pernitrate of mercury for some time, at a temperature of 347° Fahr. The mixture first becomes brown, and then gradually acquires a dark crimson colour, during which time the mercury is reduced, and settles to the bottom of the fused mixture. On pouring it off, and allowing it to cool, it forms a solid mass of impure nitrate of roseaniline, which may be purified by dissolving in water, and precipitating with common salt. M. Gerber Keller's process is nearly similar, except that he uses a lower temperature. He takes 10 parts of aniline, and 7 or 8 parts of dry pernitrate of mercury, and heats the mixture for several hours in a bath of boiling water. Messrs. Dale and Caro obtain the colour by heating a mixture of equal parts of aniline and powdered nitrate of lead, and then adding little by little a fourth part of anhydrous phosphoric acid. Other processes have also been patented, as that of Lauth and Depoully (1860), with nitric acid; that of Smith (1860), with perchloride of antimony, antimonic acid, peroxide of bismuth, stannic, ferric, mercuric, and cupric oxides; and Gerber Keller has claimed for almost every common metallic salt that is known. As might be expected, a number of these processes are practically useless, and have been claimed for no other purpose than that of anticipating the profits of future discoveries.

*Aniline Blues,*

called *azaline*, *Bleu de Paris*, *Bleu de Lyon*, *Bleu de Mulhouse*, &c. Soon after the discovery of aniline red, it was observed that certain reducing agents had the property when heated with it of changing its colour to a purple or blue. Mr. Charles Lauth, for example, in 1860, described the blue colour which was obtained from *azaleine* (nitrate of roseaniline) by means of protochloride of tin, aldehyde, the natural essences, &c.; and M. Kopp demonstrated that the same colour was produced from aniline red by means of wood spirit. But as none of these colours were permanent they were disregarded. In 1861, MM. Gérard and De Laire procured their imperial purple in the manner already mentioned, by heating equal weights of aniline and dry muriate of roseaniline, at a temperature of about 350° Fahr., for several hours. If the purple is wanted, the mass is merely treated with dilute muriatic acid until it loses its excess of aniline and aniline red, but if a pure blue is required, the acid treatment is continued until all the red tint is removed, and a pure blue remains. This is finally dissolved in acetic acid, or methylated spirit, and the blue dye, called *Bleu de Lyon*, is obtained. The same blue, but called *Bleu de Paris*, was procured by MM. Persoz, De Luynes, and Salvetat, by heating a mixture of aniline and dry bichloride of mercury in a sealed tube for 30 hours, at a temperature of 356° Fahr. The mass when cold is dissolved in boiling water, and the colour precipitated by means of common salt. This operation is repeated until the blue is quite free from the green pigment which accompanies it.

A blue, called *Bleu de Mulhouse*, may be obtained by the process patented by MM. Gros-Renaud and Schœffer in 1861, and which consists in boiling a solution of *azaleine* (nitrate of roseaniline) with gum lac and carbonate of soda for some time; and another blue, named *azuline*, has been produced by M. Marnas by a like treatment of a substance called *peonine*, with eight times its weight of aniline; and the residuum is purified with a succession of solvents, as water acidulated with muriatic or sulphuric acid, then hot naphtha, then caustic alkali, and finally with water acidulated with muriatic acid. The azuline, or blue colour, which remains is soluble in spirit and forms a rich blue dye. Blues are also produced by the action of numerous oxidizing agents on aniline or its salts, as by a solution of hypochlorous acid (Hofmann), by a solution of chlorate of potash and muriatic acid (Fritzsche), by peroxide of hydrogen (Lauth), by perchloride of iron or red prussiate of potash (Kopp); by peroxide of manganese or pernitrate of iron and hydrochloric acid (Scheurer-Kestner), by bichromate of potash and acid (Willm); and I have obtained it by oxidizing the sulphate of aniline by means of the oxygen disengaged at the positive pole of a battery. In all these cases the blue is very difficult of solution, for it resists the action of every solvent but strong sulphuric acid. Taking advantage of this, Mr. Nicholson in 1862 patented a process for purifying the blue colouring matter, by dissolving it in concentrated sulphuric acid, and then heating it for half an hour at a temperature of 302° Fahr. By diluting it with water it is precipitated in a modified condition, for it is now soluble in pure water. Dr. Hofmann ascertained that it was a substitution compound of roseaniline, in which three equivalents of hydrogen had been substituted by three equivalents of a hydrocarbon called phenyl ($C_{12}$ $H_5$); he therefore named it tryphenylic-roseaniline, and this suggested the possibility of substituting other hydrocarbons, as methyl ($C_2$ $H_3$), ethyl ($C_4$ $H_5$), amyl ($C_{10}$ $H_{11}$), &c., in which he was successful by acting upon roseaniline with the iodides of these radicals, and thus producing ethylic, methylic, and amylic substitution compounds of a rich blue and purple colour, called Hofmann's blues. Very recently the change has been effected by a more direct process without the aid of the iodide, but by heating a mixture of aniline, muriatic acid, and methylic alcohol under pressure, and then heating with iodine and chlorate of potash, or other oxidizing agent.

*Aniline Greens.*

Most of the blue substances just described become green by the action of acids, and again acquire a blue colour when they are washed or treated with alkalies. It has also been noticed that in certain states of oxidation, aniline acquires a green tint; but all attempts to utilize this colour failed until, in 1860, Messrs. Calvert, Clift, and Lowe patented the process for producing it upon the fabric. Their process was to prepare the fabric with chlorate of potash, and then to print upon it with acid muriate of aniline. In a few hours a beautiful bright green colour, called *emeraldine*, gradually appeared, and it was fixed by merely washing it with water. If a blue tint were required, the fabric was passed through a solution of bichromate of potash, when the oxidation of the aniline was carried still further, and a dark indigo blue, called *azurine*, was produced.

A green colour may also be obtained by heating a mixture of two parts fuchsine with three parts strong sulphuric acid and one part water. When the solution of the fuchsine is complete it is allowed to cool, and four parts of aldehyde are added. The mixture is again heated until it is a bright blue colour without a trace of violet. It is then treated with a boiling solution of hyposulphite of soda, and filtered. The residue upon the filter is to be boiled in water and filtered while hot. After standing 24 hours it deposits a green precipitate.

*Aniline Black.*

Several processes have been proposed for making a black dye from aniline, as by acting on aniline with an oxide of chlorine, and then with a salt of copper; but the colour is not of sufficient importance to command attention.

*Aniline Yellow,*

called *chrysaniline*, or *phosphine*. This colour was first obtained by Mr. Nicholson, in 1861. He procured it from the residuum of roseaniline by the action of steam, whereby a dirty yellow solution was obtained. On adding nitric acid to the solution, the yellow dye was thrown down as a nitrate of little solubility, and by decomposing it with an alkali the base is set free, which either alone or in the form of a soluble salt communicates a rich yellow colour to silk and wool.

These are the principal colours obtained from aniline, and it may be of interest to examine the leading properties of these remarkable compounds. At first you will have remarked that the bases of nearly all the aniline colours are very insoluble in water, ether, and coal naphtha. They are more soluble in water acidulated with the mineral acids, and are still more soluble in acetic acid. Alcohol, however, is the great solvent for them. You will likewise observe that they are generally precipitated from their saline solutions by alkalies and by common salt, and in this manner they are generally purified. Tannin also produces an insoluble compound with them, and thus they are often fixed upon vegetable fabrics. They are endowed with great powers of resistance, for they will bear the action of strong sulphuric acid without undergoing decomposition, but they cannot resist the action of powerful oxidizing agents, as chlorine, chloride of lime, or nitric acid. Reducing agents, as sulphide of ammonium and protosulphate of iron, destroy their colour; but the action is not permanent, for on exposure to the air oxygen is absorbed, and the colour reappears.

The bases themselves are not generally coloured, but they acquire their characteristic tints when they combine with acids. I have here the colourless, or nearly colourless, solutions of roseaniline, mauvine, and aniline blue, and you will remark that directly I expose them to the vapours of an acid (acetic) their characteristic tints appear.

The tinctorial power of these dyes is remarkably great. If, for example, I put a little Magenta, mauve, or aniline blue upon paper, and then shake off the powder as completely as possible, there yet remains sufficient to give deep tints when I blow a fine spray of alcohol and acetic acid upon the paper.

The affinity of animal substances, as silk, wool, feathers, horn, ivory, leather, &c, is so great that the dye instantly combines with them, and produces a permanent stain. The affinity, indeed, is so great that, as you will here see, a piece of flannel will completely absorb and remove the colouring matter from its solution in water. Vegetable tissues, however, have no such affinity for the colour, and therefore processes must be adopted for fixing the dye upon cotton and linen fabrics. One of these processes is to prepare the fabric with some animal substance, as albumen, serum of blood, the caseine of milk, or the gluten of wheaten flour. Advantage is also taken of the power which tannin has of combining with the colour and rendering it insoluble. The process of Messrs. Puller and Perkin is to soak the cotton tissue in a decoction of shumach, or other tannin material,

for an hour or two, and then in a solution of stannate of soda for another hour; after which it is dipped into dilute sulphuric acid, and is then ready for the dye. By these contrivances the aniline colours are made fast upon all kinds of vegetable fabrics.

Starch appears to have the power of fixing the colours, for if shaken with weak solutions of them it will absorb the colour, and by falling to the bottom of the liquid leave the solution colourless.

The rationale of the change which takes place during the formation of the several colours is not altogether clear, although there can be no doubt that the essential part of it is the oxidation of aniline; for, as I have already stated, when a salt of aniline is exposed to the action of nascent oxygen set free from the positive pole of a galvanic battery, the characteristic tints of aniline are successively and quickly produced. At first there is bright yellow, then green, blue, violet, and lastly red, as if these were the successive phases of oxidation. The researches of Dr. Hofmann have demonstrated that all the aniline reds are salts of a well defined base, which he has named *rosaniline;* and the more recent inquiries of MM. de Laire, Girard, and Chapoteaut have shown that there are four such bases entering into the composition of coal-tar colours, as *violaniline, mauvaniline, rosaniline*, and *chrysotoluidine*, which form an arithmetical series advancing by successive additions of $C_2H_2$, thus:—

| | |
|---|---|
| Violaniline . . . . . | $C_{36}H_{15}N_3$ |
| Mauvaniline . . . . . | $C_{38}H_{17}N_3$ |
| Rosaniline . . . . . | $C_{40}H_{19}N_3$ |
| Chrysotoluidine . . . . | $C_{42}H_{21}N_3$ |

Each of these bodies is produced in the same manner, by the oxidation and removal of 6 atoms of hydrogen from 3 atoms of aniline, or 3 atoms of toluidine, or 3 atoms of the mixed bases, thus:—

6 atoms of hydrogen from 3 atoms of aniline produce *violaniline.*

$$\underbrace{3\,(C_{12}H_7N)}_{\text{Aniline.}} - H_6 = \underbrace{C_{36}H_{15}N_3}_{\text{Violaniline.}}$$

6 atoms of hydrogen from 2 atoms of aniline and 1 of toluidine produce *mauvaniline.*

$$\underbrace{2\,(C_{12}H_7N)}_{\text{Aniline.}} + \underbrace{C_{14}H_9N}_{\text{Toluidine.}} - H_6 = \underbrace{C_{38}H_{17}N_3}_{\text{Mauvaniline.}}$$

6 atoms of hydrogen from 1 atom of aniline and 2 of toluidine produce *rosaniline.*

$$\underbrace{C_{12}H_7N}_{\text{Aniline.}} + \underbrace{2\,(C_{14}H_9N)}_{\text{Toluidine.}} - H_6 = \underbrace{C_{40}H_{19}N_3}_{\text{Rosaniline.}}$$

and 6 atoms of hydrogen from 3 atoms of toluidine produce *chrysotoluidine.*

$$\underbrace{3\,(C_{14}H_9N)}_{\text{Toluidine.}} - H_6 = \underbrace{C_{42}H_{21}N_3}_{\text{Chrysotoluidine.}}$$

These colour bases are perfectly homologous in all respects, for they not only unite with acids to form salts which crystallize very freely, and which have remarkable tinctorial power, but they also contain within them three atoms of typic hydrogen, which may be replaced by certain radicals, as of the alcohols, &c.—methyl, ethyl, phenyl, &c.—forming derivative compounds of like basic properties, and frequently of high tinctorial quality.

The best known of these bases is *rosaniline*, which in its anhydrous condition is represented by the formula

$$C_{40}H_{19}N_3,$$

but which always contains two atoms of water in the hydrated state in which it is set free from its compounds, thus:—

$$C_{40}H_{19}N_3,2\,HO.$$

It is readily obtained by decomposing its salts—the aniline reds—with an excess of alkali, soda, or ammonia, and in this state it falls as a dirty yellow or brownish-yellow precipitate; but by careful purification it occurs as a colourless base, which quickly becomes rose-red on exposure to any acid, even the carbonic acid of the atmosphere. It is nearly insoluble in water, slightly so in ammonia, and very soluble in alcohol, forming a deep red solution. Ether and coal-tar naphtha have no solvent action upon it. It combines with one, two, or three equivalents of acid to form salts which crystallize very readily, the first of them, the mono-acid salts, being remarkable for their lustrous metallic or bronze-like appearance and their beautiful rose-red solutions; these, indeed, are the true colouring compounds, the most important of which are the following:—

*Fuchsine*, or muriate of rosaniline, $C_{40}H_{19}N_3,HCl$
*Azaleine*, or *Magenta*, the nitrate, $C_{40}H_{19}N_3,HNO_6$
*Roseine*, the acetate . . . . . $C_{40}H_{19}N_3,HC_4H_3O_4$

It was the last-named salt which composed the splendid bronze-like crystals of the crowns which were exhibited in 1862 by Mr. Nicholson. And, besides these, there are sulphate, arseniate, oxalate, chromate, tannate, &c., of rosaniline. Most of them are freely soluble in water and in spirit, but the tannate is so insoluble in water that it is used for fixing the colour upon calico, and for recovering the dye from very weak solutions. To this end the otherwise waste products of aniline red are treated with a fresh infusion of nutgalls, and in a short time the rosaniline is precipitated in the form of a magnificent red lake of tannate of rosaniline, as you here see, leaving the solution quite colourless. This lake is soluble in spirit and in acetic acid, and may be thus used for dyeing.

The salts of rosaniline with two equivalents of acid have not been studied, and even those with three of acid are not of any technical value.

Under the influence of reducing agents, as sulphide of ammonium, or the nascent hydrogen evolved from zinc when a solution of rosaniline in muriatic acid is left in contact with the metal, it is rapidly decolorized, and is transformed into a new base, which Dr. Hofmann has named *leucaniline.* This is effected by the absorption of two atoms of hydrogen, thus:—

$$\underbrace{C_{40}H_{19}N_3}_{\text{Rosaniline.}} + 2\,H = \underbrace{C_{40}H_{21}N_3}_{\text{Leucaniline.}}$$

The new base occurs in the form of colourless acicular crystals, which are scarcely at all soluble in water, but freely so in alcohol. The salts of it are also colourless, or dazzling white, although they reacquire the red tint of rosaniline when their solutions are exposed to the action of oxidizing agents, or even to the air.

Dr. Hofmann has ascertained that there is still another base derivable from, or closely related to, rosaniline—viz., *chrysaniline.* It is procured from the residual, or waste product of rosaniline, by the action of steam and nitric acid, as I have already described. It contains two atoms less of hydrogen than rosaniline, and therefore it stands in its relation to this base as rosaniline does to leucaniline, thus:—

| | |
|---|---|
| *Chrysaniline* . . . . . | $C_{40}H_{17}N_3$ |
| *Rosaniline* . . . . . | $C_{40}H_{19}N_3$ |
| *Leucaniline* . . . . . | $C_{40}H_{21}N_3$ |

It is slightly soluble in water, and it forms yellow salts with acids, one of which, the nitrate, is a very insoluble compound. The solutions of the base and of its salts communicate a splendid golden yellow colour to animal tissues.

Aniline blues are, for the most part, substitution compounds of aniline red, the three atoms of typic hydrogen being replaced by three of an organic radical. The blue, for example, which is produced by the action of aniline on a salt of rosaniline, is a compound in which the three atoms of hydrogen are replaced by three of phenyl, thus:—

*Aniline red*, or *Rosaniline* . . . . . $C_{40}H_{19}N_3$
*Aniline blue*, or *Triphenylic rosaniline* $C_{40}\left\{\begin{matrix}H_{16}\\(C_{12}H_5)_3\end{matrix}\right\}N_3$

And its production when aniline is heated with a salt of rosaniline is accompanied with the evolution of ammonia, disregarding the acid of the compound, thus:—

$$C_{40}H_{19}N_3 + 3\,C_{12}H_7N = C_{40}\left\{\begin{matrix}H_{16}\\(C_{12}H_5)_3\end{matrix}\right\}N_3 + 3\,NH_3$$

Other substitution compounds, in which the three atoms of hydrogen are replaced by three of methyl, ethyl, amyl, &c., have been produced by Dr. Hofmann by the action of the iodides of these radicals on the salts of rosaniline, or even by the more simple and direct process of heating them with the alcohols of the radicals under pressure. All these compounds are basic in their character, and they mostly form, with one equivalent of an acid, the blue colours which are known as Hofmann's blue and violet, and the violet of Paris.

The other bases of aniline and toluidine colours have not been so well studied, but it is very probable that the reactions and general properties of *violaniline, mauvaniline*, and *chrysotoluidine* are very similar to the preceding, and that they are capable of forming the like reduction and substitution bases.

*Carbolic Acid Colours.*

Four or five dyes have already been produced from this compound, namely, *rosolic acid* or *aurine*, *peonene* or *coralline*, *azuline*, and *picric acid.*

*Rosolic acid* is contained in coal tar, as was first demonstrated by Runge in 1834, who extracted it from the dark red-brown residual product of carbolic acid by means of spirit; and on treating the solution with caustic lime, he separated a brown compound (brunolate of lime), and obtained a red solution (rosolate of lime), from which he precipitated the rosolic acid as a dark red powder by the aid of acetic acid. Other observers, as M. Tschelnitz in 1857, and Dr. Hugo Müller still later, noticed that the common carbolate of lime of commerce became red on exposure to the air, and that this was due to the formation of rosolate and brunolate of lime; but we are indebted to Dr. Angus Smith, and more recently to M. Jourdan, for an explanation of the changes which thus take place in carbolate of lime, and for suggestions for a process for making the dye on a commercial scale. They found that when the vapour of carbolic acid is passed over a hot mixture of soda and peroxide of manganese, or peroxide of mercury, oxygen is absorbed and rosolic acid produced, thus:—

$$\underbrace{2\,C_{12}H_6O_2}_{\text{Carbolic acid.}} + O_2 = \underbrace{C_{24}H_{12}O_6}_{\text{Rosolic acid.}}$$

The residue yields to water a rich red solution of rosolate of soda, from which the rosolic acid can be obtained by precipitating by means of acetic acid.

The production of the acid commercially has been accomplished and patented by Messrs. Guinon, Marnas, and Bonnet. They mix together about 23 parts, by weight, of carbolic acid, 10 to 20 of oxalic acid, and from 7 to 14 of commercial sulphuric acid, and heat them for three hours or until the desired colour is obtained. The product is well washed with water to remove the excess of acid, and the residue, which is impure rosolic acid (*aurine*), is a soft pitchy material with a green shade of cantharides; but as the acid is insoluble in water and cannot well be fixed upon fabrics, the patentees have converted it into a new compound, named *peonine*, by incorporating nitrogen with it.

*Peonine* or *coralline* is produced by heating 1 part of the crude rosolic acid with 2 parts of ammonia of commerce, for three hours, in a closed metallic vessel at a temperature of 270° Fahr. The product is a thick liquid of considerable tinctorial power, and which gives with acids a deep red insoluble or fast colour, which may be so applied to silk, wool, and other textile fabrics.

*Azuline*, as I have already stated, is a blue colour, produced by heating 5 parts of peonine with 6 or 8 of aniline, and keeping them at nearly the boiling-point for several hours.

*Picric acid*, or *carbazotic acid*, or *trinitrophenic acid*, is obtained by oxidizing carbolic acid with nitric acid. It was formerly procured by a like treatment of indigo and the yellow resin (*Xanthorrhea hastilis*) of Australia, and also by the action of nitric acid upon the coal naphtha which distils between 300° and 400° Fahr.

When carbolic acid is cautiously dropped into strong nitric acid it is attacked with great violence and with a hissing noise, as you may observe; and, according to the strength of the acid, there are produced one or more of the following substitution compounds:—

| | |
|---|---|
| *Carbolic acid* . . . . . | $C_{12}H_6O_2$ |
| *Mononitrophenic acid*. . . | $C_{12}H_5NO_4O_2$ |
| *Binitrophenic acid* . . . | $C_{12}H_4(NO_4)_2O_2$ |
| *Trinitrophenic acid* . . . | $C_{12}H_3(NO_4)_3O_2$ |

If the acid be strong enough the last compound is alone produced, and when the mixture cools it deposits crystals of picric acid. These are purified by dissolving them in water, neutralizing the solution with carbonate of soda, evaporating, and crystallizing. The crystals of the soda salt yield, when they are decomposed with dilute sulphuric acid, fine yellow, pearly looking crystals, or plates of picric acid. They are soluble in from 80 to 90 parts of cold water, and they possess considerable tintorial power—a grain of the acid in 300,000 grains of water will give a moderate shade of yellow to 1000 grains of silk. The colour is best applied with a mordaunt of alum and cream of tartar; cotton fabrics do not retain the colour, and hence it becomes a test for such tissues when mixed with wool or silk. The solution is very bitter, and, as it is not a poisonous compound, it has been thought that it might be used instead of hops for beer. It forms yellow salts with the alkalies, and with metallic oxides, and most of them are highly fulminating or explosive when heated.

If picric acid is submitted to the action of reducing agents it produces red colours of great beauty; thus *picramic acid* is formed when the acid is reduced by means of a hot solution of protosulphate of iron (Wohler), or by the aid of sulphuretted hydrogen or sulphide of ammonium (Girard).

$$\underbrace{C_{12}H_3(NO_4)_3O_2}_{\text{Picric acid.}} + 6\,HS = \underbrace{C_{12}H_5(NO_4)_2NO_2}_{\text{Picramic acid.}} + 4\,HO + S_6$$

The acid thus obtained is in the form of brilliant ruby-red crystals, which are soluble in alcohol and ether, and slightly soluble in water.

*Isopurpuric acid* is another red product of picric acid. It is procured from it by the process of M. Hlasiwetz, which consists in dissolving 2 parts of cyanide of potassium in 4 of water, and when it is heated to a temperature of 140° Fahr., adding, little by little, a solution of 1 part of picric acid in 9 of water. The liquid evolves ammonia and prussic acid, and, on cooling, deposits an abundant crop of crystals. These are washed with a little cold water, and then dissolved in boiling water to which a little carbonate of soda has been added; as the solution cools it yields tolerably pure crystals of isopurpurate of potash. They have a red-brown colour by transmitted light, and a green metallic by reflected. By substituting ammonia for potash, as by dissolving the crystals in boiling water and adding sal-ammoniac, there is formed, as the solution cools, beautiful red crystals of isopurpurate of ammonia, which is isomeric with the brilliant red dye called *murexide*, and which, but for the cheaper forms of aniline colours, would have been an important dye; for it gives to silk and wool, when mordaunted with corrosive sublimate, a magnificent purple, rivalling the purple of Tyre; and with a mordaunt of zinc it produces a brilliant yellow. The colours are very fast, but they will not resist the action of the sulphurous acid so constantly found in the atmosphere of towns.

We know but little of the homologues of carbolic acid—namely, cresylic acid ($C_{14}$ $H_8$ $O_3$)—and the higher members of the series, which may, perhaps, be capable of yielding corresponding coloured compounds.

*Naphthaline Colours*

have not yet been successfully produced, although many attempts have been made to utilize it in this way; indeed, as far back as 1858, Strecker drew attention to the similitude of chloroxynaphthalic acid and the red colouring constituent of madder (alizarine), there being required only the substitution of hydrogen for the chlorine to change it into madder red; and in 1861, M. Z. Roussin announced that he had actually converted naphthaline into alizarine. His process was first to act on naphthaline with nitric acid, and so change it into binitronaphthaline, thus:—

$$\underbrace{C_{20}\ H_8} + 2\ H\ NO_6 = \underbrace{C_{20}\ H_6\ (NO_4)_2} + 4\ HO$$

Naphthaline. Binitronaphthaline.

This is a crystalline body, which he next dissolved, little by little, in concentrated sulphuric acid. The mixture was then heated to a temperature of 392° Fahr., and small portions of granulated zinc were cautiously added to it. After a time sulphurous acid began to be evolved, and the nitronaphthaline was slowly converted into a red colouring matter, which he thought was alizarine. The change appeared to be as follows:—

$$\underbrace{C_{20}\ H_6\ (NO_4)_2} + H_8 = \underbrace{C_{20}\ H_8\ O_6} + 2\ NH_3 + 2\ HO$$

Binitronaphthaline. Alizarine.

By diluting the mixture with 8 or 10 times its bulk of boiling water, and quickly filtering, the solution yielded, as it cooled, brilliant red crystals. But they differ from alizarine in many essential particulars, especially in not giving the purple and chocolate tints, as alizarine does, with iron and alumina mordaunts.

Mr. Perkin has also devoted attention to this subject, but his labours have not been very successful.

*Naphthalamine* is a compound which bears the same relation to naphthaline that aniline does to benzole, and it is made by somewhat similar transformations. Messrs. Calvert, of the Tower Chemical Works, have produced it very largely, in the hope that, by oxidation in the same way as aniline and toluidine are oxidized, colours might be obtained. In this manner Mr. Brunner produced in Mr. Calvert's laboratory a very fine purple, by heating it with arsenic acid. M. Du Wildes obtained a like result with the nitrates of mercury; and M. Roussin has shown how fabrics may be dyed of a red colour by acting on muriate of naphthalamine with nitrite of potash, and how a violet-red tint may be obtained by heating a mixture of naphthalamine and dry bichloride of mercury in a sealed tube, at a temperature of 356°, for many hours; and by heating a mixture of muriate of naphthalamine and protochloride of tin to a temperature of 472° Fahr. The purple-red colour is in both cases insoluble in water but soluble in alcohol, and may be thus used as a dye. Messrs. Guinon, Marnas, and Bonnet have also proposed to use it in the place of aniline for the production of a blue colour; but I am not aware that any of these processes have been put into actual practice.

And now, in conclusion, as I have been compelled, for want of time, to deal very briefly and generally with this subject, I will merely state that those who are anxious to pursue the matter further will find many memoirs on the subject, to which they may refer with advantage. In this country there have been published the valuable report of Dr. Hofmann, at page 119 of the chemical section of the "Reports of Juries" on the International Exhibition of 1862, and the "Lectures by Dr. Calvert on Coal-Tar Colours, in Relation to Dyeing and Calico Printing;" and on the Continent the following have been published:—

1. "Examen des Matières Colorantes Artificielles dérivées du Goudron de Houille." Par E. Kopp. 1861.
2. "Matières Colorantes dérivées du Goudron de Houille." Par Ad. Wurtz. 1862.
3. "Manufacture and Properties of Aniline Colours, and the Bodies used in their Preparation." By MM. Depoully Brothers. 1866. (*Chemical News*, vol xiv., pp. 77, 89, 157.)
4. "Technologie des Anilins." "Handbuch der Fabrikation des Anilins, und der von ihm derivirten Farben." M. Reimann. 1866.

In addition to which there are numerous papers on the subject in the scientific journals of the last six years, several of which have appeared, either in full or in abstract, in the JOURNAL OF GAS LIGHTING.

The CHAIRMAN said he thought the members would agree with him that the cordial thanks of the association were due to Dr. Letheby for the very able and interesting lecture to which they had just listened.

The resolution was very cordially adopted.

Dr. LETHEBY acknowledged the vote, and said he felt it right to state that he was indebted to Messrs. Simpson and Maule for the specimens of dyed fabrics exhibited, also to Messrs. Wilson and Lowe for the specimens of carbolic acid on the table. But for the kindness of those gentlemen he should not have had the pleasure of showing these things to the menbers, and he thought it right that he should recognize that kindness by mentioning it to the association.

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WEDNESDAY, JUNE 12.

The President took the chair this morning at eleven o'clock.

Mr. GODDARD read the following paper:—

ON THE APPLICATION OF LIQUID HYDROCARBONS AS A SUBSTITUTE FOR CANNEL IN THE MANUFACTURE OF GAS OF HIGH ILLUMINATING POWER.

The subject which I have ventured to bring under the consideration of this meeting is of the greatest importance at the present time. In the early history of gas lighting, oil and fatty matter was extensively used in the manufacture of gas, and while a very superior illuminating agent was produced, it was soon found to be so costly, as compared with the use of coal, that it was abandoned as being commercially unprofitable. Of late the demand, both by the public and the Legislature, for gas of a higher illuminating power than can be produced from ordinary gas coals, has led to the adoption of a portion of cannel with the coals, until its use has become a necessity with those companies which are required by their Acts of Incorporation to supply gas of a certain standard of illuminosity. The cannel coal measures being comparatively limited, the increased demand has resulted in a corresponding increase in price; and the recent application of cannel in the manufacture of petroleum has still further enhanced its value. It therefore becomes a matter of grave inquiry how gas of high illuminating power is to be produced at such a cost as will yield a profit to the gas companies, who, whatever may be the cost of production, are limited as to the price at which it shall be sold to the public.

The waste products from the oil-works in combination with coal have been employed as a substitute for cannel, and it is the purpose of this paper to direct attention to some of these materials. In the rectification of cotton-seed oil, the residue is employed in the manufacture of stearine for candle-making, and the refuse from which, known in commerce as cotton-seed pitch, produces gas of great illuminating power and in large volume. The result of experiments with this material has been furnished to me by Mr. Crow, as follows:—One ton of cotton-seed pitch will produce 22,000 cubic feet of gas, equal in illuminating power to 30 sperm candles, each consuming 2 grains per minute. But the supply of this material is too limited to come into general use.

In many parts of the country is to be found in immense quantities, schist or schist clay, commonly known as shale, from which oleaginous matter can, readily be produced, and letters patent have been recently taken out by Mr. M'Kenzie for utilizing this oil in the production of gas. The invention consists in minutely pulverizing one ton of bituminous coal, or duff, and intimately combining it with, first, 25, 30, or 35 gallons of crude shale oil, or petroleum; or, secondly, with one-half of these oils mixed with one-half of what is known as bottoms, or residue, in the distillation of these oils. Partly with the view of taking off the water from the oil and thoroughly mixing the thick residues with the light oils, and also partly to produce a quicker and more complete combination of the oil with the coal, Mr. M'Kenzie slightly heats the oil, and in that state, or shortly thereafter, thoroughly mixes and combines them. The quantities of oil used, whether 25, 30, or 35 gallons, are mainly regulated by the quality and quantity of gas desired from the material. If 18-candle gas or under be desired, 25 gallons of oil are used; should 24-candle gas or under be desired, 30 gallons are used; and should over 24-candle gas be desired, 35 gallons are used.

It may be that an oil or coal deficient in the properties desired will require 2 to 5 gallons more oil; but that we understand to be the extent of the variation. If petroleum be used instead of shale oil, the results will be better, but there is so little difference that, commercially, shale is the better oil for the purpose.

The only other element in the manufacture is the pulverization of the coal. If the minimum quantity of oil is to be used, the coal requires to be ground a little rougher than when 30 gallons are used; while, if 35 gallons are to be used, it requires to be very fine. The reason for this we understand to be that the greater the quantity of oil the finer must be the particles of the coal, so that the oil may be absorbed. If 35 gallons of oil were put into coal adapted for 25 gallons only, there would be condensation, and the gas would not be permanent to the extent to which the coal could not absorb thoroughly the oil. While the result would be good, it would be much less satisfactory, and would raise doubts as to the permanency of the gas produced.

There is no peculiarity about the use of the material. It is charged in the usual way, but requires a little less time in the retort than ordinary coal. The only thing requiring care in its treatment when first used at any works, is that the ascension-pipes be thoroughly cleaned. As to the results secured, these have been reported very high, varying from 12,000 to 14,000 cubic feet per ton, according to the quantity of oil used, the illuminating power of the gas being from 18 to 20 candles. The coke produced is of first-rate quality, and this forms one of the valuable features of the invention. Letters patent for accomplishing the same object have been secured by Mr. John Hamilton, in which crude coal oil (creosote) or other mineral oil, together with a small portion of naphthaline, are boiled, and, whilst in a hot state, are poured over a quantity of sifted or pulverized coal, known in the trade as "coal-duff," coal, culm, or other pulverized coal may be used. The mixture may be made in a pug-mill or other suitable mixing machine, and is then allowed to stand for 24 hours or thereabouts, so as to permit a complete combination of the gases of the coal with those of the oil and naphthaline. The result is an artificial gas-producing material, and the following proportions are found to produce good effects:—1 ton of coal, 20 to 30 gallons of coal oil, and 5 lbs. of naphthaline. From this mixture the patentee states that he has obtained 15,000 cubic feet of gas of high illuminating power.

The licence for the sole manufacture of M'Kenzie's patent material has been secured for England by Mr. Thomas Vaughan, of Middlesboro', who is now erecting large works at Merton, near Seaham Harbour, and who will be able shortly to supply the material equal to the best Boghead cannel, at about half the price of cannel.

Several attempts have been made to employ petroleum instead of coal for the production of gas, and, in the state of New York and other parts of America, where petroleum is very cheap and coals expensive, the experiments have proved very satisfactory.

The process employed at Homer and Courtland, in the state of New York, may not be without interest to this assembly. At Homer, two retorts were fixed of the following dimensions:—Length, 7½ feet; breadth, 16 inches; height, 12 inches. Two vertical pipes are cast on each retort, for the purpose of supplying water and petroleum. The retorts are placed horizontally in an arch, exactly the same as ordinary coal-gas retorts, for which they can be substituted without much trouble or expense.

Each retort is divided into three chambers, called the petroleum, the water, and the coke chambers respectively. Petroleum and water are in-

troduced in continuous streams through the tubes before described, so that when once a barrel of petroleum is placed at a sufficient height to allow a pipe provided with a stop-cock to feed the retort, the fluid may be admitted, and the process of conversion into gas goes on without further trouble until the barrel is exhausted. Each retort will produce about 500 cubic feet of gas per hour, and 11 gallons of petroleum are consumed in the production of 1000 feet of gas; but, as this gas has at the least three times the illuminating power of ordinary coal gas, it will be seen that two petroleum retorts, of the same dimensions as coal-gas retorts, will yield in 24 hours 24,000 cubic feet of petroleum gas—the equivalent of 72,000 cubic feet of coal gas—or as much as 24 ordinary retorts, charged with 150 lbs. of coal each every five hours, can produce in 24 hours.

This advantage in favour of petroleum gas refers only to America, where coal gas is much more expensive and petroleum much cheaper than in this country.

I have now very briefly, and I am conscious very imperfectly, placed before you the best known practical means of using liquid hydrocarbons for enriching gas; and when we consider the almost inexhaustible supply of material from which they may be obtained (as referred to in an admirable letter which recently appeared in the *Times*), in what are called the bituminous shales, such as the Kimmeridge clay of Dorsetshire, and also in large districts of Yorkshire; in the form of bitumen in the pitch lakes of Trinidad; and in the form of liquid oil, as in Pennsylvania, Rangoon, and numberless other places—in one or other form it is found in England, Scotland, France, Switzerland, Italy, the Greek Islands, Hungary, and Sicily; it is found in Russia, European and Asiatic, in Turkey and Asia Minor, and in Persia; it overflows the Caspian Sea; it is found in the salt-wells of China, in North America, in California (where it flows out to sea), in Curacoa, in Cuba, and Barbadoes—I say when we consider the immense stores of this material with which Nature has provided us, in almost every part of the habitable globe, the probable inference is, that it is destined eventually to become a most important agent in the manufacture of gas, and also as fuel in generating steam—a subject also of great importance to the commercial interests of the company, and which I hope will form the subject of a paper at the next meeting of this association.

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*Trial of M'Kenzie's Patent Gas Coal at the Middlesborough Gas-Works.*
Furnished by John Dunning, Esq.

| | |
|---|---|
| Total quantity of coal used . . . . | 51 tons 10 cwt. |
| Total quantity of gas made . . . . | 508,377 cub. ft. |
| Amount of gas per ton . . . . . | 9,871 „ |

Illuminating power varied from 24 to 27 candles during the experiment, tested every hour of the day.

| | Tons. | cwt. | qrs. | lbs. |
|---|---|---|---|---|
| Total quantity of coke produced. . . | 42 | 11 | 2 | 2 |
| Used as under— | | | | |
| About p. ct. | Tons. | cwt. | qrs. | lbs. |
| 14 Engine-fires . . | 6 | 1 | 1 | 0 |
| 65 Retort-fires . . | 27 | 16 | 2 | 26 |
| 21 Sale heap . . . | 8 | 13 | 2 | 4 |
| 100 | 42 | 11 | 2 | 2 |

Total quantity of tar, 600 gallons = 11¾ gallons per ton.
Quantity of ammonia water, 360 gallons = 7 gallons per ton.
Lime used was about 50 per cent. in excess of that used for the ordinary Durham coal, which is 1s. per 1000.
Coke was very good in appearance, but light in texture; hence it took more water, and this accounts for securing increase in quantity. In the fires it was not so lasting as the ordinary coke, and clinkered a good deal more.

Mr. Paterson said, like all the previous papers read by Mr. Goddard, the present was of a most important and practical character. It must be very interesting to every member of the association to know what could be produced from the bituminous shales referred to. But he thought it would be very desirable to ascertain more definitely what, taking the normal illuminating power of coal gas at 14 candles, the expense to the companies would be to raise that illuminating power, by the means described, to 20 or 23 candles, so as to be able to judge whether it would be cheaper to use the shale oil for that purpose than cannel, as at present.

Mr. Eldridge asked what naphthaline Mr. Goddard alluded to in describing the invention patented by Mr. Hamilton.

Mr. Goddard said it was the naphthaline produced in the distillation of tar. With regard to the remarks made by Mr. Paterson, he might say that he apprehended the material patented by Mr. M'Kenzie would be used in the same way as cannel, using just as much as would be required to raise the illuminating power of the gas to the desired standard, and as that material could be supplied at half the cost of cannel to produce the same effect, he thought it would commend itself very strongly to the attention of the gas world. He had before him some specimens of the coke resulting from M'Kenzie's material solely, and also some coke from 90 per cent. of Durham coal and 10 per cent. of that mixture. The use of this per centage would raise the illuminating power of the gas to something over 14 or 15 candles.

Mr. Warner inquired the price of the material.

Mr. Goddard said he understood the mixture of which he exhibited a specimen, would be supplied in London at 25s. per ton. It consisted of coal finely ground, in an ordinary pug-mill, with shale oil, in the proportion of 30 gallons to a ton, which was just sufficient to absorb the oil.

The Chairman observed that the mixture of the two would produce about 23 cwt. altogether. He inquired whether it was sold by the ton.

Mr. Goddard said it was, and would be delivered in London at 25s., or the patentee would grant licences for any gas company to manufacture their own material.

The Chairman: The patentee puts it forward as an artificial cannel to supersede the ordinary cannel.

Mr. Goddard: It is to supersede cannel, using up that which is comparatively worthless, and also to work out a large amount of duff which has not hitherto been applied to any useful purpose.

Mr. Dunning said the cost of the material on the Middlesborough works was 19s. 2d. per ton, which he took to be a high price. The cost of the duff coal at the collieries was not more than 2s. per ton; the cost of the oil only about 2½d. or 3d. per gallon. Taken at 2½d. it represented 6s. 3d. per ton. Then there was the cost of manufacture, which was not very heavy when the plant was put into proper form. At present a new mill was being erected at Middlesborough of sufficient capacity to grind a large quantity per day, and he believed eventually the material would be supplied in London at less than Mr. Goddard had mentioned. His own impression was that it would be about 20s., but that, of course, rested with the proprietors. He believed they were very anxious to introduce it to the gas companies, and would leave no stone unturned to make it pay eventually. He (Mr. Dunning) had found in practical working that it entirely superseded cannel, of which he formerly used from 10 to 15 per cent. to maintain the illuminating power of his gas at 14 or 15 candles. The coke, a specimen of which Mr. Goddard had exhibited, was produced from a mixture such as was stated. When that coke was being manufactured, he was using altogether M'Kenzie's patent coal, in order to test thoroughly and efficiently the best mode of employing it, and the result of his experience, after a few trials, was that it would not do to work it by itself, but must be used as cannel was used—viz., in small proportions mixed with ordinary coal. When working it by itself, he never could get more than 9800 feet of gas per ton. The illuminating power, however, was very high—viz., from 24 to 27 candles, and sometimes even reaching 30 candles; in fact it was almost impossible occasionally to measure it, and they had to change the burners constantly. The Argand burner would not consume it properly, and they had to resort to a small jet. He believed, if carefully tested, it would have been found to range higher than 30 candles illuminating power. The proportion generally employed was 10 per cent., and with that he obtained an illuminating power of 16 or 17 candles all the way through, and a good coke was produced. There was one peculiarity about the coke from the mixture, which was rather a drawback to the use of the material itself. The coke was good in appearance, but light in texture, hence it took more water to slack it. There was rather more than 16 cwt. to the ton of coal, slacked in the ordinary mode. His object in the trial he made was simply to ascertain whether the material produced more or less coke, and he found that there was a slight increase in the quantity, weighed in the ordinary way from the retort-house, after being slacked by water. But in the fires it was not nearly so lasting as the ordinary coke; more of it was required, and it clinkered a great deal, so that the coke by itself would not do. The quantity of tar produced was 11¾ gallons per ton, and of ammoniacal liquor 7 gallons.

The Chairman asked what coal it was made from.

Mr. Dunning said it was made from the refuse duff at the colliery.

The Chairman said there might have been a great deal of iron in it.

Mr. Dunning thought there was a great deal. His own impression was that the best mode of applying the invention in large works would be for the gas companies to set up a proper mill, sift out the small coal from that which came to them in the ordinary way, and grind it up and mix it with the oil upon their own premises. They would thus be able to buy their oil in the best markets, and see that they got the best quality for the purpose.

The Chairman asked what oil it was that Mr. Dunning's material was composed of.

Mr. Dunning believed it was common shale oil, obtained in the neighbourhood of Glasgow—not Boghead, but common shale oil from the district. He understood the patentees were taking every pains to secure a proper quality of oil, and were testing every sample they received, so as to be able to send out an article they could guarantee.

The Chairman asked whether the 2½d. or 3d. per gallon for the oil which had been mentioned was the price in Scotland or the price as delivered.

Mr. Dunning said that was the price in the Scotch port. He had been asked to describe the mode of charging the retort. It was charged in the ordinary way with a shovel.

The Chairman inquired whether if sent to London the material would be sent in a kind of brick.

Mr. Dunning said it would be sent in bulk. It cost 15s. per ton at Merton, but the railway company made him pay 4s. 2d. per ton for its carriage 30 miles, charging it as a manufactured article. If it could be made upon the works of a gas company, it would not cost more than 15s. per ton.

The Chairman: Does it readily part with any of its oil in the shape of vapour so as to form an explosive mixture?

Mr. Dunning: Not the slightest. We have had it laid in bulk for two months, and never noticed anything of the kind. There is one satisfactory result I might mention. I have tried it to see whether there was more absorption of the gas in water. I filled a gasholder, and found there was no appreciable difference in two days.

The Chairman: Have you tried it in frosty weather? Do you know whether the gas made from this material condenses readily and loses any of its illuminating power?

Mr. Dunning: We have not noticed it. We have not had much frost since we began to work it. So far as I have been able to observe, it does not condense more than any other gas.

Mr. Goddard said he had the opportunity of taking a few photometric observations at the Middlesborough works at the time this material was being used, and the photometer showed that the gas was of an illuminating power of 27 candles with a jet burner; the quantity made per ton of coal being nearly 10,000 cubic feet. Mr. Evans, at the Chartered works, had been using it for some little time. He ground up the coal himself, and mixed it with the oil on the premises. The price which he had been giving for the shale oil was 5d. per gallon. Upon inquiry at the oil distillers, he (Mr. Goddard) found that it was hardly probable the oil would be obtained for less than 4½d. or 5d. per gallon.

Mr. Eldridge asked whether the results just given by Mr. Goddard were obtained when using only 10 per cent. of the material.

Mr. GODDARD said it was not; it was while using the material alone, as coal entirely.

Mr. ELDRIDGE thought it was clear the material could only be advantageously employed where the standard of illuminating power was high. When the standard was only 14 candles, it could not be used with profit.

Mr. GODDARD: It is entirely so.

Mr. DOUGLAS, of Portsea, asked whether, assuming a gas company kept a considerable stock of the material, say for four or five months, it would depreciate to any extent; also whether there was any smell, or anything that would cause a nuisance from keeping the material on the works in bulk; and further, what royalty would be required for the use of the patent, supposing a gas company thought fit to prepare the material on their own works.

Mr. GODDARD said he could not answer those questions. He had been anxious to bring this matter, being somewhat of a novelty, before the meeting, but he had not gone into the question of its commercial value. He looked at it in this light, that there were certain companies which were compelled to use cannel in order to increase the illuminating power of their gas to the parliamentary standard; cannel coal was becoming more expensive every day as it became more largely used, and the question therefore became one of importance how to obtain the same amount of illuminating power produced from it at a less cost. This material, he apprehended, would be used in a precisely similar manner to cannel, but as to what amount of royalty would be required by the patentee for leave to make it on the gas companies premises, that was a point he had not gone into, because it was simply a commercial matter.

Mr. DOUGLAS said perhaps Mr. Dunning could answer his questions, especially with regard to the storeage. He had had the subject brought before him, and had entertained the idea of trying the material, but he should be glad first to be informed whether it deteriorated in value by being kept in store, and also whether it occasioned any nuisance on the works.

Mr. DUNNING said there was no offensive smell from the material; there was a smell, but nothing offensive, and it could not be perceived outside the shed in which it was placed. With regard to depreciation in value, he did not think there was much in that. The oil was not volatile, and he had had the material lying on the open ground for a month together, at the end of which time there was no difference in it. Mr. Eldridge asked what results were obtained with a mixture of 10 per cent. He (Mr. Dunning) might state that since he sent the returns to Mr. Goddard he had tried a few more experiments, and got results from working with 10 per cent. of the mixture. The illuminating power of the gas was reduced from 24 or 27 candles down to 16 or 17. The quantity produced per ton was nearly the same—10,000 cubic feet. He did not take the quantity of tar and ammoniacal liquor, but he ascertained that the coke was much improved in quality, and that less of it was required for use in the engine. The results upon the whole were briefly these. The quantity of coke produced was about 16 cwt. per ton, after being slacked. Of that about 7½ per cent. = 1·2 went to the engine fires as against 2·24; 45½ per cent. to the retort fires = 7·2 as against 10·40; and 4·7 per cent. to the sale heap = 7·5 as against 3·36. It would thus be seen that this all went to confirm what he had stated as his first impression, that the proper way to use it was as a mixture with common coal and not by itself. The common coal used was Byers Green and South Brancepeth coal in equal proportions. Under ordinary circumstances he obtained 9600 or 9800 cubic feet of gas per ton from that coal, of 14 candles illuminating power. Previous to employing this material he used cannel, sometimes from Wigan and sometimes from Scotland, buying it of course in the cheapest market.

Mr. NEWBIGGING said if he understood Mr. Goddard correctly, in the course of the reading of his paper he stated that 50 per cent. more lime was used in the process of purifying the gas made from this material than when ordinary cannel coal was employed in the retort. He would like to know whether that increased per centage of lime was rendered necessary by the presence of an increased quantity of sulphur, or whether it was due to a larger proportion of carbonic acid gas being formed.

Mr. DUNNING, referring to a previous inquiry, said he knew, from the patentee himself, that the royalty for the use of this invention was 1s. per ton of the material, and any gentleman who corresponded with Mr. Vaughan would find this to be the case.

The CHAIRMAN: That would render it necessary to weigh the material.

Mr. DUNNING, replying to Mr. Newbigging, said he believed the increased quantity of sulphur present in the trial made by him at the Middlesborough Gas-Works was owing to the nature of the coal employed, which contained a great deal of pyrites. He did not find, when using 10 per cent. only of the material, that the purifiers were much affected by it, but when it was used by itself they were affected.

The CHAIRMAN said the meeting would like to be informed upon another subject. In many gas-works they used round and large coal, and the members would like to know what would be the effect of casting this powder into the retorts in which the large coal was used. Where small coal was used it could be mixed up and the coke would all consolidate together; but supposing, as was the case over a large part of the kingdom, large round coal was put into the retort, then how would Mr. Dunning deal with this powder?

Mr. DUNNING said just the same. At his works they used large unscreened coal as it came from the pit to the bank, having pieces as big as his head and duff with it. The men cracked the large pieces with hammers, and this material was mixed with the mass. There might be half a shovel full of the material with a large lump of coal going into the retort together.

The CHAIRMAN remarked that in the south of England the coal was all large coal. They used the cherry coal—the flint coal, which was not in powder, but in large pieces. What effect would casting the powder upon these large lumps have upon the coke?

Mr. DUNNING said he had not worked with that kind of coal, but his own impression was that it would run all into one mass.

The CHAIRMAN: But it does not run at all. This coal does not cake.

Mr. DUNNING: Then you would have this caking into its own coke, and the other would come out in its own form.

Mr. ANDERSON said from the remarks which had been made with regard to this substance, his own impression was that there was no advantage from its use; and for this reason: they learned from the paper just read that in manufacturing gas wholly from the substance they could obtain 16 cwt. of coke per ton of coal. Now, they all knew that a ton of coal would not produce above 13 cwt. of coke, therefore this coke must absorb 3 cwt. more of water than ordinary coke did. In burning that coke they had to evaporate that 3 cwt. of water, and this no doubt was the explanation why 65 per cent. of all the coke made was required beneath the retorts. Now, if it required 60 or 65 per cent. of the coke for the retort fires, and the cost of this stuff was 19s. or 20s. per ton, it appeared to him, without going into the figures, that there was really no advantage compared with using a small proportion of cannel coal. The details of the paper touched very closely upon an experiment that had come under his own observation, and which he would briefly refer to. At one of the gas-works with which he was connected the manager took some of his small coal—in fact, sifted it out of the ordinary coal, and mixed with it as much common tar as it would absorb. He then pressed the small coal and tar combined into small bricks, and he told him (Mr. Anderson) that for three or four weeks—until, in fact, the stuff so made was exhausted—he had by its use raised the illuminating power of the gas to the same extent as he had formerly done with about 5 per cent. of cannel. The circumstances only came before him in a purely accidental manner, and he had not ascertained the quantities of the stuff employed, but he mentioned the fact because it seemed to be a question full of interest. He suggested to the members present that they might before next year try some experiments upon the subject. He knew that there were prejudices against making gas from tar, and that it had been said it would not mix with the other gas. That might, perhaps, be because of bad manipulation. He fancied that to manufacture gas from a portion of the stuff now brought under notice, mixed with common coal, was a bad system of manipulation, because it was very evident that the gas from this material would come off much more readily than from the other coal in the retort—that it would volatilize its gas, perhaps, in one-fourth of the time that would be necessary to distil it from ordinary coal; so that if they were to take a single retort and charge it with this stuff in the proportion of 10 per cent. to the coal employed, very likely during the first hour of the charge the gas would have a high illuminating power, whereas after the second hour they would only obtain gas of the ordinary illuminating power. On this account he thought the better plan would be to make the stuff into bricks. He had had the advantage of seeing some of the bricks made burned in a common fire, and he found they gave out a genial heating flame for some two or three hours. If the stuff had been thrown upon the fire in its loose state, his impression was that the flame would have gone off in a short time, and then there would have been only the ordinary coal burning. If they could increase the illuminating power of their gas by using a quantity of tar, it would not only be a benefit to the companies, but if there was anything in the patented system, would enable them to get this patented stuff cheaper.

Mr. DOUGLAS (Newcastle) thought before the material brought under notice was condemned, it ought to be tried. As to Mr. Anderson's remark about the coke, he thought that difficulty might be met by selling the whole of the 16 cwt., and using coke from other sources under the retorts. Every one connected with gas-works would be delighted if this invention could be brought to practical account, and, for his part, he was determined to go home and try it before he pronounced an opinion. Next year, perhaps, the association would hear more about it.

Mr. DUNNING, with reference to the remarks of Mr. Anderson, said he did not find practically any difficulty in meeting the objection he raised about this material sooner volatilizing gas. They charged their retorts, so many benches, every half hour, so that what was volatilized immediately in one set of retorts was mixed in the hydraulic main with the gas from other benches which had gone on a little further, and they did not find any difference in the working. Their exhauster worked as regularly as before, and there was no difficulty in any part of the process. They had a uniform quality of gas delivered into the town, and did not find any great condensation in the gasholders or in the mains.

Mr. FRASER said it appeared to him that one objection which might have arisen with reference to this matter, was the deterioration in the quality of the coke. He did not know what class of customers Mr. Dunning supplied in his own town, but if they were as particular as some that he knew, they would object to it on account of the additional moisture. It occurred to him that they might get rid of that difficulty by setting apart a portion of the retort-house for the production of gas of a higher illuminating power, and then mixing it with the inferior gas. This coke would thus be kept apart from the other coke, and used upon the works for heating the boilers or furnaces. From what he had heard it seemed that this was a very feasible and workable mode, in substitution of cannel, of getting up the illuminating power, and that the association were deeply indebted to Mr. Goddard for bringing it under their notice, and also to Mr. Dunning for the explanations given. He felt assured that if it did no further good, it would set the members to work like Mr. Douglas, and that they would go home with the intention to test the thing for themselves, so that at the next meeting they would be prepared to bring forward the results of practical experience.

Mr. GODDARD, in reply, said he should have been glad if the paper

had led to some further discussion, for he felt that it was one of those subjects which should come under the observation of such a meeting. One of the great objects of an association of this nature was to bring under the consideration of its members those novelties in connexion with their special duties and engagements which might come to light during the year. It was with this view, that, at the request of the committee, he took upon himself, though he had but little practical acquaintance with the subject, to prepare the paper which he had had the honour to bring under the consideration of the meeting.

Mr. HUTCHINSON, of Barnsley, read the following paper:—

SOME REMARKS ON THE EXPLOSIVE PROPERTIES OF FIRE-DAMP AND COAL GAS, WITH PARTICULARS OF EXPERIMENTS MADE IN LIGHTING PORTIONS OF THE OAKS COLLIERY WITH PIT GAS.

I feel it necessary to offer some little apology for introducing the subject of fire-damp to the notice of this meeting. At first sight it may appear to be foreign to the objects of this association, but, as by our rules these objects are defined to be "all matters connected with gas engineering, manufacture, and finance, and to facilitate the exchange of information and ideas amongst its members," the contents of this paper may be said to fall within the latter clause. Having had the honour of being a member of this association since its commencement, and having always attended its meetings with pleasure, I should feel sorry to be so unfortunate as to be the means of introducing any matter for discussion which would not be acceptable to my brother members.

As I am fully persuaded that it is for want of a more thorough and practical acquaintance with the nature, properties, and management of fire-damp that these terrible explosions so frequently occur, and knowing that it is essentially a *gas* that does all the mischief, I should indeed be delighted if this paper should be the means of creating a lively discussion, and thereby bringing out any new idea of the means of producing a really good and safe light for the use of the miner, which may be calculated to prevent a repetition of such fearful calamities as those which we have just witnessed in our neighbourhood at the above-named colliery.

It is certain that the coal cannot be worked without at the same time liberating the gas; it is equally certain that we cannot carry on the numerous and important manufacturing and domestic operations to which coal is now applied, and deemed indispensable, without its aid. It becomes, therefore, a matter of importance to investigate whether this dangerous gas cannot, in some cases, at least, be collected and utilized for the purpose of lighting the main thoroughfares and other safe parts of the mine, instead of being allowed to circulate, and become mixed with air; thus forming the explosive compound which has at various times committed such fearful ravages. If, therefore, this gas can possibly be so utilized, the subject must be one of great interest to an Association of Gas Managers, although the gas is manufactured by Nature, without the aid of either stokers or retorts, on a grand scale of which we have really very little conception; all the apparatus and appliances which we ordinarily think necessary to the carrying on of a modern gas-work are dispensed with. We appear to have no definite idea of the magnitude of the operations or the time taken to conduct the process, yet it is evident to our senses that coal gas is, or has been, made and stored up on a scale so immense as to totally eclipse the ideas of even our modern gas engineers. We cannot say whether they are 6 hour or 6000 year charges, or whether oxide or lime is used for purification; but, as I shall proceed to show you, a pure gas is given off from the coal strata—and this, indeed, from the coal itself, after it has been dug from the earth and exposed to the atmosphere, as the explosions on board some of our coal-laden vessels will testify.

This subject would certainly appear to be more directly interesting to the mining engineer, but, seeing the close connexion that exists between the two professions, I trust you will excuse any little deviation I may make from the strict letter laid down in our rules and regulations, in giving a short account of some interesting experiments which I made, some five years ago, at the Oaks Colliery, near Barnsley, where I reside, and where there are a number of collieries of some magnitude, of which Barnsley is the centre or head-quarters; so that I frequently come in contact with the various managers or under-viewers.

It thus happened that on July 21, 1862, Mr. George Minto, then under ground viewer of the now unfortunately world-wide known Oaks Colliery, called upon me, inquiring if I could give him any assistance or advice under the following circumstances:—He said, "We have a large blower of gas in our pit, which has been going on for some time; it seems to be very strong and pure; do you think it would be possible to turn it to any account, such as lighting the mine?" He excited my curiosity; I felt interested in the question, and entered into the matter at once, and made arrangements with him to visit the scene of action the next day.

I had frequently been in a pit before, but not on such an errand as that; and knowing the dangerous nature of the work I was going about, not only to myself, but to the whole of the men employed (for at this time the colliery was in full work), I very naturally took every precaution I could think of to insure my safe return to the surface—a proceeding which caused no little amusement to the underground viewer, my only companion, who was more familiar with such scenes than myself.

The fearful explosion that has since occurred at this colliery may show to some extent the danger encountered in making such experiments, and give some additional interest to the following details, an account of which I have often been requested to write. I may here state that I made notes at the time of every particular likely to be of service, which notes I have fortunately preserved, and which, with your kind permission, I will read over, and endeavour to make as interesting as I can. I will divest the subject as much as possible of colliery technicalities, but perhaps some few are necessary in order that you may follow me, in my remarks, with profit.

I met Mr. Minto at the time appointed, one o'clock, who furnished me with a suitable flannel dress; we descended the shaft, about 300 yards deep, and were supplied with a stick and a safety-lamp each from the lamp cabin at the pit bottom. This cabin was a model of cleanliness and order, being whitewashed and made to appear very comfortable; here all the lamps are left by the workmen on leaving for the day, and they are supplied with oil and trimmed ready for use on their arrival next morning. All the lamps used in the colliery are always safely locked before leaving this place; here was also kept a barometer and thermometer. We next proceeded down the engine-plane, about 800 yards, which dips about 6 inches to the yard, and then some 500 or 600 yards on the level. All is life and activity; there is a sufficiency of fresh air, and we can walk erect, the seam of coal being about 9 feet thick. We next proceeded to the gas-pit. This is a branch road from the level on the right hand; at the entrance is a large gate or door, made of wooden bars, so that the air can circulate through it; this door or gate is locked, and a board hung upon it with the word "DANGER" written thereon; we open this door, which is closed after us and again locked, no one but the underground viewer being allowed to have a key. We have not gone far before we encounter some large stones, or masses of rock, which have fallen from the roof. We scramble over these, but as we proceed things get worse, and I wished myself out again; however, the underviewer encouraged me with, "Come along, man—never fear! I dare go into your gasometer with this Stephenson's lamp;" and seeing he had such unbounded confidence in his safety-lamp, I began to feel a little ashamed of my want of confidence. But I could not easily forget the danger, from various sources, with which we were surrounded. Imagine our position if anything had gone wrong. We were about a mile from the surface; I knew we were in an explosive atmosphere, which any defect in the lamps might ignite; our lights might be extinguished, from various causes, and leave us in total darkness; or we might be rendered insensible from breathing the noxious gases; a stone might fall from the roof, &c. Any of these events might happen any minute, and these facts, coupled with the blackness, darkness, dampness, and wild desolation of the place, and with the roaring, bubbling, hissing noise of the escaping gas in the distance, was enough to make any one tremble.

At length we arrive at the place where the gas is actually issuing, which is a small pit or well, about 4 feet in diameter and 25 feet deep, and had been sunk three or four years ago to prove the throw or fault, the vein of coal having been suddenly lost at this point. The engineers had been compelled to abandon this search for the coal, in consequence of so much gas and water being given off as to render it unsafe to proceed further, and had filled up the little pit with any sort of *débris*. Through this rubbish and water the gas boiled up incessantly, from the seam of coal below, with a very violent agitation. We made a careful examination of the place, and then made the best of our way to the surface, where we arrived safely, to my great satisfaction.

A number of questions naturally forced themselves upon one's mind, such as the following:—What kind of gas is it? is it inflammable? is it given off at a uniform rate or pressure? what illuminating power has it? what quantity is given off per hour? can it be conducted to and consumed in a safe part of the mine, &c., &c. To answer these and other questions it is absolutely necessary that some practical experiments should be made at the source from whence the gas issues, in order to learn something of its nature and properties; so the next day we paid a second visit to the dreary cavern, if such a mild term may be applied to such a place. On this occasion one felt a little more at home, having travelled the ground over before, and having been prepared with all the apparatus I could think of at the moment, which could be used without danger, for we well knew that to use a naked light in such a place would be instant death; so we proceeded to make a number of experiments, and ascertained the following facts:—

The gas, or fire-damp, escaped plentifully, with a loud bubbling, roaring, hissing noise at the surface of the water, which was 63° Fahr. It might also be heard issuing out of the coal, or crevices of the rocks, in various situations round about us. It had no smell, or at least so slight that there is a difficulty to find words to describe it; yet it could be recognized by persons accustomed to it. With a large funnel inverted over one of the blowers in the water, and a 6 ft. length of india-rubber tubing, the pressure-gauge gave 7 inches. I caught abundance of gas, filling a number of test-tubes, bottles, and bladders. At the end of this tube the thermometer held in a stream of gas indicated 63° Fahr., the same temperature as the water in the pit. I then applied the following tests:—Red and blue litmus, lead and turmeric papers, and lime water. No reaction was shown on any of them.

Here I felt a strong desire to see the action of the gas on the safety-lamp, and requested Mr. Minto to give me an illustration. This he did by gradually raising his lamp near the roof of the mine, to find the lightest portion of the gas, which floats on the top nearest the roof. The action was beautiful; the light soon showed a struggle for life, and danger was indicated by a bluish wave hovering about the top of the lamp within the gauze, which finally extinguished the lamp altogether, but no worse result happened than leaving one lamp in darkness; bearing in mind we had each a Stephenson's lamp, which was held down near the floor of the mine, so that we had still one light burning. We then made our way to the cabin at the bottom of the engine-plane—a place of safety, with abundance of fresh air, where naked lights were used. Here we tried the effect of a light on the small samples of the gas collected, which was found to burn quietly away at the mouth of the tube or bottle. Thus ended our second visit.

On our third visit, Mr. Dymond, one of the proprietors of the mine, accompanied us, and was certainly anxious to have everything done towards freeing the mine of the gas that could be done with safety, and was desirous of witnessing the experiments. We now collected the gas in larger quantities, filled a Pepy's gasholder, and removed it to the cabin before mentioned, and tried the gas with an Argand, union jet, and bat's-wing burners, and found the gas to burn, to all appearances, equal to the manufactured coal gas. It sparkled a little with the particles of coal dust that were flying about, but otherwise it burnt very well. I was fully convinced of the practicability of the plan suggested of utilizing the gas for lighting a portion of the mine, which would not only be a considerable saving in oil, &c., but, so far as it could be collected and burnt, render the mine so much safer, by destroying the explosibility of the gas so consumed, instead of the said gas escaping into and circulating in an explosible form through the colliery workings, until it escapes from the upcast shaft.

But before any steps could be taken towards so desirable an object, it was necessary to obtain the consent of Mr. Woodhouse, the mining engineer, who had the sole control of all matters connected with the ventilation of the Oaks Colliery; so two bladders full of the gas were at once forwarded to that gentleman, who happened to be at a neighbouring colliery, and he compared the gas contained in the bladders with the coal gas manufactured on the pit premises, and declared it to be equal to the artificial gas so made, so that he at once gave full authority to proceed with the experiments, and to have everything done that was needful, with a view of lighting a portion of the mine.

Mr. Dymond then gave instructions for the road to the gas-pit to be cleared of rubbish and fallen rocks, so that free access could be obtained thereto, and no expense to be spared in order to render all as safe as possible. A staff of men were now set to work, and the stones and rubbish removed; the well was cleared out some 10 or 12 feet deep and walled up; plates of sheet lead were laid down and covered with clay puddle, to force as much of the gas as possible through the water. A small gasholder, 4 feet deep and 6 feet diameter with a 6-inch T-pipe on the top, was then procured and fixed over the gas-pit; at one end of this T-pipe was a slide-valve which could be opened or shut as required; at the other end was a bend connected to the pipes which conveyed the gas to the engine-plane, &c., where it could be consumed with safety; 4-inch pipes were laid from

the gas-pit to the bottom of the engine-plane, from which point 3-inch and 2-inch pipes were continued to the bottom of the shaft. Into the 6-inch T-pipe on the top of the holder was inserted a short piece of ½-inch tubing and a 12-inch pressure-gauge attached thereto, but the water was instantly blown out; indeed, when the valve and all other outlets were closed, the force of gas was so strong that the weight of two men was not sufficient to keep the gasholder down; it also forced the water from under the holder, although it dipped 12 inches. To keep the holder in its position, we found it necessary to place pieces of timber between the roof of the mine and top of the gasholder. I could now collect gas in greater quantity with comparative ease, which I did in a Pepy's gasholder and india-rubber gas-bag, which were were removed for greater convenience in testing.

I made various trials of the quantity of gas given off per hour, with a 30-light gas-meter. I obtained from 295 to 300 feet per hour, or 7200 feet per day. We were fully aware that a great deal more was given off, but the difficulty was how to collect it under the gasholder. The small pit being partially filled up, the gas was forced laterally into the crevices of the rocks around, so that the puddle was often thrown up. The pressure in the gasholder could be regulated by opening or closing the valve more or less, and allowing the surplus gas to escape. Being anxious to prove if the gas was given off at a uniform rate, I set the valve so as to maintain 1 inch head of water, and attached a registering pressure-gauge to the ½-inch pipe. The pressure remained constant—viz., 1 inch during the whole 24 hours. I tried various pressures with like results. Thus proving beyond doubt that this simple and inexpensive apparatus might be depended upon for collecting and furnishing a regular and constant supply of gas to the mine. I then tested the illuminating power, which I found equal to 10 sperm candles; in one instance I obtained 12 candles, but was somewhat surprised, after repeated trials with Cooper's tube, to find I could get no condensation by the bromine test, although the ordinary coal gas gave 4½ to 5 per cent.; neither could I obtain any indication of carbonic oxide or carbonic acid. The specific gravity was ·517. The chemical test-papers were again applied, as before mentioned, with like results. I found the loudest explosion to occur when the gas was mixed with nine times its volume of air.

At length the pipes were laid, the burners attached and ready for lighting. Then came a very critical point. We were anxious to be satisfied that the gas contained in the pipe, to which the light was to be applied, was in such a condition, at the moment, that the light could not by any possible means travel back to the gas-pit, and thereby cause an explosion. I felt quite certain upon this point from observing the pressure and other indications, but in matters of such importance there should be no room to doubt. For the first light I connected an Argand burner with a glass tube filled with shot, after that a ½-inch pipe about 1 foot in length filled with wire driven in lengthwise, previously proving by direct experiment that it was impossible for a light to run back under such circumstances. The first light was now applied with perfect success, and continued to burn quite satisfactorily; others were now lighted without fear, and, by degrees, some 60 lights were put on, which continued to burn day and night, without intermission, from that time until the 12th of December last, on which date a most terrific explosion occurred in the mine, with the particulars of which most of you will be familiar. This caused the death of nearly 400 unfortunate individuals, 285 of whom still remain entombed in the pit, which it was found necessary to close in order to put out the fire. Before finally closing up the pit, a 10-inch pipe was placed up the side of the shaft, so as to give vent to the pent-up gases, which are given off in large quantities even up to the present date; indeed, the mine now appears to be one huge gasometer. On Friday last, the 7th inst., the quantity of gas given off was near 50,000 feet per hour; however, this quantity varies considerably with atmospheric changes. An account of the changes which occur in barometer, thermometer, and pressure-gauge is taken every hour, and faithfully recorded in the colliery office. The gas now given off appears identical with that which I found to issue from the gas-pit before mentioned, with this exception, that it contains about 3 per cent. of carbonic acid, no trace of which could be discovered in the other.

I had originally purposed giving a general summary of the present state of our knowledge of the nature and properties of fire-damp, and the various means that have hitherto been proposed to avoid such terrible calamities as now so frequently occur in our colliery districts. There are ample materials for rendering such a subject highly interesting, especially if illustrated with experiments, but seeing that it would not be appropriate to a meeting like the present, I abandoned the idea; however, I cannot dismiss this subject without giving a short account of the different gases with which it appears desirable the miner should make himself acquainted. They consist of the following—viz., atmospheric air, fire-damp, black-damp, and after-damp.

First and foremost in importance is pure atmospheric air. This, as we are all aware, is essential to maintain life. It is composed of a mixture of two gases—viz., nitrogen, four-fifths, and oxygen, one-fifth, with minute portions of other gases which we need not now take into consideration. This atmosphere, which surrounds the earth, extends in varying degrees of density, about 45 miles from its surface, on which it exerts a pressure equal to 15 lbs. to the square inch at the level of the sea. It is the receptacle of all the gases and vapours, organic and inorganic, which are constantly escaping from the earth and sea. Air is a transparent, colourless, elastic, tasteless fluid, its two constituents being permanent gases. Heat simply expands it, and within certain temperatures with great uniformity. In combusion the oxygen alone is consumed, the nitrogen is set free and mixes with the carbonic acid produced at the expense of the oxygen. Air is, therefore, rapidly contaminated by the process, and in a confined space the nitrogen and carbonic acid, as a result of the heat of combustion, accumulate in the upper part of the vessel or apartment. Neither of these gases are respirable, and neither will support ordinary combustion, as may be illustrated by many beautiful experiments.

Air is usually taken as the standard of specific gravity for gases, being for this purpose called 1·000 or 1000; 100 cubic inches of dry air at the mean temperature (60 Fahr.) and pressure 30 inches are considered to weigh 31 grains. Air is 815 times lighter than water; compared with hydrogen, its density is as 14·4 to 1.

It is calculated that 1 cubic inch at the surface of the earth would expand to 12,000 cubic inches at the extreme limit of the atmosphere (45 miles). Air is not a definite chemical compound, but a mechanical mixture of two different gases, in which we live, move, and breathe. The temperature of the atmosphere diminishes about 1° Fahr. for each 350 feet of ascent. A column of water 33 feet in height, or a column of air 45 miles in height, each having the area of a square inch, would be equal in pressure to a column of mercury 30 inches in height. These different heights correspond to the respective specific gravities of liquids. The influence of this pressure on the volume of gases may be easily demonstrated, and should be thoroughly understood by both the gas and mining engineer, a practical acquaintance with the laws which govern and regulate the elasticity of the air being of vital importance to the latter. The elasticity of a gas is increased directly as the pressure. The volume of a gas is increased inversely as the pressure. The density of the air is in a direct ratio to the compressing force. With the pressure of half an atmosphere the volume is doubled, and with a pressure of two atmospheres it is reduced to one-half. It is the same for all gases and vapours (above the boiling-points of their liquids), whatever may be their respective specific gravities. The volume of a gas increases $\frac{1}{480}$th part of its volume at 32° Fahr. for every degree of added temperature. As in all fluids, the pressure is equal in all directions.

Numerous analyses of the air have been made by chemists of repute. The proportion of oxygen varies from 20 to 21 per cent.

| | By Volume. | Volume. | Per Cent. by Weight. |
|---|---|---|---|
| Oxygen | 20·80 | 1 | 23·10 |
| Nitrogen | 79·20 | 4 | 76·90 |
| | 100·00 | 5 | 100·00 |

*Fire-Damp, Marsh Gas, Pit Gas, or Light Carburetted Hydrogen.*—Symbol, $CH_2$; sp. gr., ·552. 100 cubic inches weigh 17·12 grains. Specific gravity as compared with hydrogen is as 8 to 1.

Fire-damp is a natural product which issues from the ground, and admits of being kindled. It is a product of decomposition from beds of coal, and when it mingles with the air forms an explosive mixture. It is a colourless, invisible, inodorous gas, scarcely soluble in water; it does not support combustion or respiration. When breathed in a pure state it is fatal to animal life, but is not very noxious when mixed with air, even when it forms 8 or 10 per cent. of the mixture, the miners can work in it; however, when it is very strong it has been known to render them insensible, but the usual effects are a tightness across the forehead, with headache, which happens some time before insensibility takes place.

Fire-damp alone does not burn or explode, it must be mixed with air or oxygen before either of these phenomena can show itself. If mixed with too much air, explosiveness is again lost. If the proportion of air be diminished to three or four times that of the fire-damp, or increased to more than fourteen times its measure, explosion does not happen; for where the volume of air is very small an amount of oxygen sufficient to burn the fire-damp is not furnished; where the quantity of air is too large it prevents the spread of flame by conducting away heat, and preventing the temperature rising high enough to inflame the combustible gas. If mingled with twice its volume of oxygen or ten times its volume of air, it detonates powerfully. When collected and consumed at the mouth of a gas-jar, it burns away quietly with a yellowish white light, somewhat similar to coal gas, but if the light is passed into the jar it is extinguished instantly. There is no immediate chemical test for the presence of this gas.

Fire-damp cannot be kindled unless it be raised to a white heat. A candle or oil lamp gives a white heat, which at once determines an explosion if introduced into an explosive atmosphere. Fire-damp being very light, little more than half as heavy as air, it ascends, collects, and lodges in hollows or recesses at the upper parts of the workings, and would of its own gravity readily escape at the surface into the open air, if there was a free course open for it to do so; so that, while the lower part or floor may be ventilated and free from danger, a light brought near the roof might lead to a dangerous explosion.

When an explosion does occur, the life of the miner is likely to be sacrificed from several distinct causes, arising, first, from burning, as the very atmosphere in which he exists is instantly one sheet of flame, beyond the power of man to control, and from which he can seldom escape; second, by the mechanical violence of the sudden expansion of the gases on their ignition, sweeping everything before it, or the contrary, a comparatively and equally frightful rush of air to fill the partial vacuum caused by the contraction of volume of the exploded gases; third, by being surrounded with, and thereby compelled to inhale, an atmosphere of carbonic acid and nitrogen. This often proves more fatal than any other cause; the entire system of ordinary ventilation being generally destroyed by the first blast; and the atmosphere pressing with equal force on downcast and upcast, the deadly gases become, as it were, bottled up in the pit with an elastic cork. The gas left after an explosion is much lighter than black-damp, or even common air, and will make its way up to the roof, whilst black-damp will lie near the floor.

The safety-lamp is, indeed, a very valuable instrument in the hands of a competent person who thoroughly understands its use, in testing for the presence of fire-damp in coal-mines. This lamp makes explosions impossible, not, as is often imagined, by preventing the fire-damp from reaching the flame within the gauze, but by preventing that flame from reaching the fire-damp without. The light is put out whilst in the very act of traversing the wire gauze, in consequence of the latter, which is an excellent conductor of heat, carrying that away, and so causing the temperature to fall below the white heat necessary for kindling the explosive mixture.

Fire-damp requires twice its volume of pure oxygen for complete combustion; the three volumes of mixed gases after detonation are condensed into one volume; they yield one volume of carbonic acid and two volumes of steam, which are immediately condensed. Now, carbonic acid contains its own bulk of oxygen; it therefore represents one of the two volumes of oxygen which disappear, whilst the other volume of oxygen has united with two volumes of hydrogen, and formed water. Light carburetted hydrogen must consequently contain twice its volume of hydrogen condensed with its own bulk of carbon vapour into the space of one volume Thus, from the composition of fire-damp, it is obvious that the gas, in exploding, renders ten times its bulk of atmospheric air unfit for respiration. The two volumes of oxygen which ten volumes of air contain produce one volume of carbonic acid and two volumes of steam, which become condensed, leaving eight volumes of *nitrogen* at liberty.

Fire-damp from different localities has been frequently analyzed, and exhibits a general uniformity in composition, consisting principally of light carburetted hydrogen, with varying quantities of carbonic acid, nitrogen, hydrogen, atmospheric air, and sometimes olefiant gas, and sulphuretted hydrogen.

*Analysis of Fire-Damp, by Professor Playfair.*

| | |
|---|---|
| Light carburetted hydrogen | 92·80 |
| Nitrogen | 6·90 |
| Oxygen | ·60 |
| Carbonic acid | ·30 |
| | 100·60 |

*Black-Damp, or Carbonic Acid.*—Symbol, $CO_2$; sp. gr., 1·52. 100 cubic inches weigh 47·08 grains. Compared with hydrogen, it is as 22 to 1.

This gas is colourless, inodorous, incombustible, inexplosive, and unfit

for respiration; it immediately extinguishes other bodies which are in a state of combustion; a candle will, however, burn in mixtures of carbonic acid and air, until the proportion of the gas reaches 20 per cent., but such mixtures would be noxious to respire. All common combustibles, such as coal, wood, oil, wax, and tallow, contain carbon as one of their component parts, so the combustion of these bodies is always attended by the production of carbonic acid. This gas possesses well-marked acid properties; it is a result of the decomposition of animal and vegetable substances, and is the chief gaseous product of combustion, respiration, and fermentation; it is about half again as heavy as air, and may be poured from one vessel to another, like water.

When so far diluted as to admit of being breathed, carbonic acid acts as a narcotic poison, producing drowsiness, entire loss of muscular power, rapidly followed by insensibility and coma. When the gas is respired in the lowest poisonous proportions, the symptoms come on very gradually, and the transition from life to death is usually tranquil.

Black-damp frequently abounds in old workings, and being absorbed by water, gives rise to the acidulous springs so abundant in coal-measures. Some mines give off this gas as well as fire-damp.

*Analysis of Carbonic Acid.*

| | Volume. | Per Cent. by Weight. |
|---|---|---|
| Carbon | 1 | 27·22 |
| Oxygen | 1 | 72·78 |
| | 1 | 100·00 |

*After-Damp, or Choke-Damp* (principally Nitrogen).—Symbol, N.; sp. gr., ·972. 100 cubic inches weigh 30·143 grains. Specific gravity, as compared with hydrogen, as 14 to 1.

Nitrogen is a permanently elastic, colourless, neutral, incombustible gas, with neither smell nor taste. It is rather lighter than atmospheric air, in which it exists in a free state. It does not support combustion or respiration; for although nitrogen is a necessary constituent of atmospheric air, yet it cannot be breathed in a pure state without destroying life. It does not appear to operate as a poison; but when breathed it simply induces suffocation, owing to the absence of free oxygen. It enters into the composition of a large number of animal and vegetable substances, and all descriptions of coal contain small quantities of this element. There is no ready test for discovering the presence of this gas. Nitrogen, mixed with carbonic acid gas, is the fatal choke or after-damp of coal-mines. It is a product of the combustion of fire-damp, and is the common cause of death to miners who are not at once killed by the explosion. This "after-damp," as the miners term it, or vitiated atmosphere that the explosion produces, is often fatal to those employed in other parts of the mine, or to the generous, but ignorant and rash survivors, who attempt to descend into the pit before it has been properly ventilated, in order to succour their comrades or to ascertain their fate.

Under the term "choke-damp" are sometimes classed all those non-explosive gases, poor in oxygen, and containing carbonic acid, which often collect in the adits and workings driven through coal-beds, and render the working of the mine extremely dangerous, if air-shafts or other means of ventilation are not employed.

*The Explosive Properties of Coal Gas.*

Manufactured coal gas, being so nearly allied to fire-damp in its explosive properties, I have little to add on this point, as many of the particulars already given under the latter section are also applicable to this gas. It may, perhaps, be desirable, before closing the paper, to give a short account of the circumstances under which an explosion is possible, or even likely to occur; for while much has been said and written on the subject of explosions, little or nothing has been done with a view to trace an escape of gas to its source, without applying a naked light, which is often the cause of fatal accidents and serious loss of property. By treating upon these accidents and describing their sources, we shall adopt the proper steps to prevent them.

Coal gas as supplied to consumers, &c., is of variable composition, according to the description of coal used, and the temperature of the distillation. It consists of a mixture of inflammable gases and vapours, all of which (except nitrogen), when mixed with certain proportions of air, are liable to explode with tremendous force. The common purified coal gas is composed of light carburetted hydrogen, olefiant gas, hydrogen carbonic acid, carbonic oxide, and nitrogen, the vapours of naphtha, &c., and bisulphuret of carbon; the disagreeable smell of coal gas is owing to the presence of these latter named vapours, as the former—viz., light carburetted hydrogen, olefiant gas, and hydrogen—when pure, are free from any odour.

Coal gas does not support combustion or respiration, but it burns readily where it meets with air, with a yellowish white flame, as we witness every day. It may be kindled in air by a *full* red heat, without flame. If we apply a red-hot bar to a jar of this gas, or to a current of gas as it issues from a jet, it will be found the iron, although visibly red, will not inflame the gas, unless the metal is heated to a bright redness.

Explosions in buildings do sometimes occur from an accumulation of gas, caused by an escape from the street-mains, service-pipes, or internal fittings, and its consequent admixture with air. There is, however, always ample warning in these cases by the powerful odour which announces the escape of coal gas, long before it has reached its explosive proportion. This odour is perceptible when mixed with 500 times its volume of air. Instead of opening doors and windows, and keeping at a distance all lights until the smell has disappeared, the ordinary practice is to apply a light for the purpose of ascertaining where the leakage has occurred. The whole of the air in a room may be in an explosive state; but coal gas has a great tendency to accumulate at the upper part. Hence it is this part that should be thoroughly ventilated. A lighted candle may burn on the floor of the room, but if raised a few feet above it, it may cause a violent explosion. In a well-closed room, if not of a very large size, every portion of air would, in the course of a short time, become explosive by admixture of the light gas.

Owing to a peculiar law which regulates the diffusion of gases, they tend, notwithstanding the greatest difference in their specific gravities to mingle uniformly in all proportions, this is proved with respect to coal gas by the smell being equally perceptible in every part of the room.

There is a difficulty in stating the exact proportion of air required to produce the greatest amount of explosion, as it is obvious, from the variable proportion of carburetted hydrogen in coal gas, and the presence of other inflammable gases and vapours, that the results obtained cannot strictly agree. They are, however, sufficiently near the truth for all practical purposes; if the gas be in too large or too small a proportion there will be no explosion, on the other hand, when this gas is unmixed with air or oxygen it extinguishes flame.

When explosion does happen, in the exertion of this explosive force much depends on the completeness with which the gases are mixed, and this must be regulated by the time during which they have been in contact, and the nearer they approach to the proper proportions for the perfect combination of the elements, the greater is the force of the explosion. A mixture of 7 parts of air and 1 part of coal gas is considered to be the most explosive compound, but this must depend on the quality of the gas. Mixtures of less than 3 of air to 1 of gas, or more than 11 of air and 1 of gas, do not explode. An explosive compound of gas, when under pressure, only ignites at the exterior of the pipe, but if the pressure be taken off the flame enters, and it explodes.

An erroneous impression exists that if a gasholder were to be rent by accident and the gas ignited, whenever the holder touched the ground, and there being no pressure, the contents would explode. This is incorrect, for no matter the size of the opening, when the pressure ceased the gas would be extinguished; but from this moment danger would commence, for a portion of the gas remaining in the crown would gradually issue and air take its place, so by degrees an explosive compound would be formed.

We had a practical illustration of this latter fact at Barnsley, on the 15th of January, 1844. Some repairs were required to be done to a gasholder-tank then in use; to this end the man-hole lid was taken off, the water pumped out, and left in this state for several days, in order to clear it of gas. The workmen were anxious to proceed, and a strong discussion was held among them the previous night as to whether the whole of the gas was out or otherwise—opposite opinions being held on this point. First thing next morning one of the workmen, in order to satisfy himself on the matter, took a lighted hand-lamp and thrust it into the man-hole to see if all was clear; an explosion was the immediate consequence, shaking and alarming the whole neighbourhood, doubling up the gasholder like paper, breaking the girders, &c., and killing the unfortunate man on the spot. I am credibly informed by several living witnesses, that they saw a large body of flame escape and ascend some height into the air, and float along the distance of several fields in length, before it was entirely extinguished. In this case the crown of the gasholder would be full of gas which could not escape above the level of the man-hole, but which would gradually become mixed with air by diffusion. Thus through ignorance this poor man lost his life, and destroyed a large amount of property.

Flame will travel through a pipe containing an explosive mixture of gas and air, if both ends are open to the atmosphere.

Gas-meters are sometimes mysteriously destroyed by explosion, even when fixed in their places. The syphon-plug, when not sealed by water, and the tap of a burner being left open, are sufficient to permit air to enter and form an explosive compound, and a light being applied to an orifice without a burner, the flame enters but does no injury beyond rendering the meter useless.

When pure coal gas is enclosed in a vessel under pressure, the moment the pressure ceases the flame is extinguished; but the flame will not follow inside the vessel as with an explosive mixture. We can look with satisfaction to the advancement science has made in connexion with the subject of gas explosions, for now we know that instead of gas being so terribly destructive as it was at no very distant period supposed to be, that when unmixed with atmospheric air or oxygen it is as harmless, as regards explosions, as the water in the tank beneath the gasholder, and that if it were possible to insert a lighted torch or taper into a holder containing gas, instead of the gas exploding the flame would be extinguished.

Considering the enormous quantity of gas manufactured and consumed daily in this country, it is truly astonishing that so few accidents caused by explosions of gas do happen.

The CHAIRMAN said he thought many gentlemen present could give information on this subject, which was especially interesting to gas companies at this time, as it had an important bearing upon the question of the construction of subways in the streets of large towns for the reception of gas-pipes. There were gentlemen present who had had some experience in connexion with explosions, and if they would give information as to the circumstances under which these explosions had occurred, a vast amount of useful information would be obtained.

Mr. METHVEN inquired of Mr. Hutchinson whether the holes through which the gas issued in the mine were generally perceptible, so that the gas could be collected as he described. He wished also to know how Mr. Hutchinson measured the quantity of gas which at present escaped from the mine, and which he thought was stated in the paper to amount to 50,000 feet an hour.

Mr. HUTCHINSON said the gas escaped from the mine from a seam of coal below. Very suddenly the level of the coal was lost, and the men sunk down a little bit to find where it had gone to. In this case the gas bubbled up through the pit, over which a gasholder was placed for the purpose of collecting it. It usually escaped out of the sides of the mine, through crevices in the coal. As respected the quantity of gas given off, he might state that he was down the mine on the previous Friday, and tried it for an hour with a pressure-gauge and a 6-inch pipe, and found it maitained a pressure of 4½ inches during an hour, and that gas was being given off, without any diminution of pressure, at the present time. He calculated that the quantity would be somewhere between 45,000 and 50,000 cubic feet per hour; but he had no means of measuring it accurately.

The CHAIRMAN: What was the length of the pipe beyond the point where you took the pressure? It is easily calculated, if you have the pressure and the distance through which it travels.

Mr. HUTCHINSON: It was somewhat about 18 inches above the pressure-gauge.

The CHAIRMAN: Then you calculated it as escaping from an aperture simply.

Mr. HUTCHINSON: Yes.

Mr. METHVEN remarked that the object of the paper was to show that this gas might be collected and burnt, and thus accident in the mine prevented. Now, he quite understood what Mr. Hutchinson said about the manner of collecting the gas, but he thought, as a rule, if it escaped from fissures in the rock there would be a difficulty in the collection.

The CHAIRMAN: I do not think that Mr. Hutchinson indicated that he could collect all the gas, and put an end to explosions. He simply indicated his opinion that sufficient gas might be collected for application to useful purposes.

Mr. HUTCHINSON: That is it.

Mr. DOUGLAS (Portsea): There is one good thing in the paper, and that is the precaution taken to prevent explosions at first. Mr. Hutchinson said that afterwards there was no danger from explosion under pressure—that the light will not travel back, and yet he seemed to have some hesitation in lighting the first light. I suppose that was with the notion of making assurance doubly sure.

The CHAIRMAN: I suppose it was not to convey that impression, because every one knows that it will travel back, but if the cooling effect in the pipe through which it passed was not sufficient to cool the gas you might get a terrific explosion.

Mr. DOUGLAS: I think he said about a mile off.

The CHAIRMAN: That will altogether depend upon the cooling power of the pipe. If you lighted the gas at the top of the shaft, you would have an explosion in the pit; but if you had a narrow pipe for the gas to pass through, sufficient to cool the gas, and then applied a light to it, the light would only go down a certain distance, and then be extinguished. That is the theory of the safety-lamp, indeed—the distance the flame has to pass at a small aperture. It is also the case with a gun-barrel. If you have a mixture of oxygen and hydrogen, which is very explosive, in a gun-barrel, provided that barrel is long enough the cooling power will prevent explosion; but if you have a short barrel you will have an explosion, in spite of its being under pressure.

Mr. ANDERSON: This is a very important matter, and a matter which I have found several gas men who have been in the business from 10 to 15 years did not understand. I have frequently heard them say that though there might be an explosive mixture in the gasholder, there was no danger in applying a light so long as the holder was floating and capable of descending. And I have frequently had to correct that error, because I say that if the gasholder contains an explosive mixture, no matter whether it is floating or at rest, there is danger of it exploding.

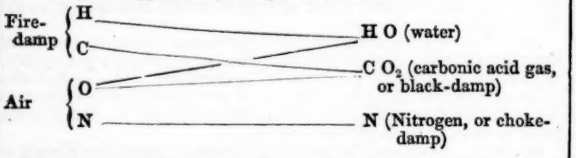
The CHAIRMAN: There is no doubt.

Mr. ANDERSON: It is a circumstance very facile to you, but I have met more than one man who did not understand it, and it is well we should know that if there is an explosive mixture in the gasholder, no matter in what position the holder may be, it is dangerous to apply a light.

Mr. GODDARD: With regard to the utilization of this natural volume of gas flowing, I would remark that unless the supply there is in the mine could be ascertained, it would be undesirable to go to a great outlay for the purpose. I have no doubt that many gentlemen present will remember that some few years ago there was at the Wallsend Colliery a constant natural stream of gas from an 8-inch pipe, the flame of which was continually burning and extended for several feet. A company was formed at Newcastle to utilize this natural gas, and just as that company were about to begin operations the flow of gas ceased altogether.

Mr. DUNNING: Another fact came under my observation when at Barnsley, and that was that at the Ackworth Colliery where there was a new pit, there was emitted a copious flow of gas for three months, which gradually grew less and less, and eventually ceased. Therefore you can hardly calculate upon a constant supply from these sources.

Mr. BLACKBURN (hon. sec.): Perhaps it may facilitate the understanding of the exact chemical action which takes place in an explosion of fire-damp if I place on the black board a diagram showing the change which occurs in the composition of the respective elements when a light is applied to the explosive mixture.




Mr. CATHELS (of the Crystal Palace District Gas-Works) read the following paper:—

## ON LEAKAGE FROM GAS-MAINS AND SERVICE-PIPES.

The loss sustained by gas companies in the distribution of their gas—which I suppose may be assumed to be not less, as a general average, than about one-eighth part of the whole quantity made, and, in particular instances, to considerably more even than that—is a question of so much importance, both in a commercial and sanitary sense, as to deserve the most careful attention of all engaged in its manufacture and distribution. Although this loss is usually, for the sake of brevity, spoken of under the general term "leakage," it is but a truism to say here that it is attributable to other causes besides that of leakage properly so called, the proportion of actual leakage to the unaccounted-for gas, doubtless, varying considerably in different establishments, and even at different times in the same establishment, depending as it does on a number of well known and constantly varying circumstances, such as the state of the distributing-pipes, their lineal extent and capacity in respect of the quantity of gas passed through them; the condition of and supervision over the consumers meters, &c. But whatever proportion leakage proper may bear to the total unaccounted-for gas in different concerns, there can be no question as to its existing to a very considerable extent wherever gas-pipes are laid, and it is this *bonâ fide* leakage only that it is proposed to consider here.

The practical question, then, that presents itself is this: Can anything more be done than is usually done, anything sufficiently inexpensive and easy of application, to lessen this loss? Well, I am afraid that question cannot be answered very hopefully, and that we must look for any mitigation of the evil possible, chiefly in doing the most we can with the present means at our disposal, by taking care that the distributing-pipes are maintained in good condition, and are of sufficient capacity to avoid having to work heavy pressures, and in having a constant knowledge of the actual requirements of the consumers during the different hours of consumption, by frequent pressures taken over the district, and adapting the initial pressures from time to time to these requirements. Neglect in the rigid performance of this last duty will infallibly lead to an increased leakage account. Careful personal attention to this part of a manager's duty in works once under my control, and where it had been previously but laxly performed, resulted in a diminution of the leakage account of as much as 3 per cent. on the make. But after all these precautions may have been taken, there will still remain the ugly fact of a leakage account, and, although varying in extent, it is at all times and in all cases sufficiently heavy to sensibly affect the profits of gas companies. I therefore think it may be worth while to consider for a moment whether the distributing-pipes, as at present made and used, are of the best possible materials and construction for the purpose, or whether they may not be susceptible of any improvements, with the view to the lessening, if possible, of this serious loss by leakage.

The jointing of the mains, for instance, is a matter of primary importance, a durable and perfectly gas-tight joint being essential for economical distribution. But the relative merits of the different kinds of joints is a question on which I do not presume to offer any decided opinion, my experience having been confined chiefly to the ordinary socket and lead joint. My limited experience of turned and bored joints, now used a good deal, has not, I am bound to say, been of a kind to recommend them to my mind in preference to the lead joint, which I think cannot be much improved on, providing the joint be well filled with lead and the setting up be properly attended to. But it is a question open to difference of opinion, and has been introduced here in order that this meeting may be favoured with the experience of gentlemen present, who may have used these as well as some of the more modern kinds of jointing—of which the late Dr. Normandy's may be taken as an example—now sometimes used. There is one thing, at any rate, in which general concurrence of opinion may be predicted—viz., that a little first saving in laying mains is but questionable economy if attended by any risk of increased leakage.

As to the materials of which mains can be constructed, cast iron is so manifestly the best and cheapest of any other at present available, that there seems to be no room for any doubt on the matter; but the same cannot, I think, be said of the form in which they are cast. The object kept in view in casting pipes is apparently wholly confined to what is considered necessary for the required strength of the pipe, without any consideration for the other important condition—viz., *the thickness of metal necessary to form a permanently secure junction with the service-pipe.* By overlooking this consideration, the obviously different conditions required in pipes that are to be used merely as trunk-mains, with which no services will be connected, and others that will be drilled and tapped for service-pipes every few feet, are entirely disregarded, both pipes being cast alike, a practice which I think I may venture to say is hardly consistent with a common-sense view of the matter. The thickness of the metal of main-pipes as ordinarily made—especially in the smaller sizes—is certainly insufficient for the connexions of services therewith, that are to be buried out of sight, it may be for many years, and on the perfect and permanent soundness of which so much depends, any imperfection involving a continual loss of gas. Now, it seems to me that this objection might be easily obviated in new mains by increasing the thickness of the metal of the pipes where the services are to be tapped into or otherwise connected with them, without increasing their thicknesses generally; and this I would propose to effect in the following manner—viz., to cast a band, or belt, with flat face, as part of the pipe, on each side of the upper half of its circumference, at angles of 45°, with centre horizontal and vertical sectional lines, as shown on drawing, these bands to extend from the back of the socket to within about 9 to 12 inches of the spigot end of the pipe, to be 2 to 2½ inches in width, and of such a thickness in addition to the thickness of the pipe as to give a total thickness of, say, an inch, which would give reasonable security for good and permanently sound joints. As these bands would be drilled and tapped in a radial line with the centre of the pipe, the services would be connected to the main by means of obtuse bends just sufficient to give the proper fall or inclination to the services, as shown. The weight of the pipe need not necessarily be increased by the addition of these bands, because the metal required for them could, without detriment, be taken out of the body of the pipe, or they might be advantageously added to pipes of the usual thicknesses.

The consideration of the question of the material best fitted for service-pipes is, like that of the mains, confined within very narrow limits. There are but two practically available materials for the purpose (their cost excluding all others)—namely, wrought iron and lead piping, the use of the former, owing to its cheapness and easy management, being all but universal. But I think that, notwithstanding its conveniences and advantages, it is doubtful whether its rapid decay in light, porous soils by oxidation is not an evil of sufficient magnitude to outweigh all its advantages. It seems to me that the use of lead tubing, though of considerably heavier first cost, would, on account of its greater durability, be, in such cases, at any rate, eventually the cheaper material. I may mention, as an illustration of the great durability of good lead when used for this purpose, that I had occasion, a few years ago, to lift some hundreds of lead services, owing to their having become too small for the increased consumption of gas in the shops and houses with which they were connected, and, although many of them had been in use upwards of 30 years, they were, on the whole, in good sound condition. The objection is sometimes raised that lead pipes, owing to their flexibility, are apt to follow any settlement of the ground in which they are laid, and so accumulate water, but that need not be apprehended if the mains are laid deep enough to give the services a good fall thereto. There was no trouble felt from that cause in the case to which I have referred, and Mr. Esson, who, I understand, has laid lead services exclusively for years in Cheltenham and other places with which he is professionally connected, will, I dare say, be able to tell us that he has not experienced any such inconvenience from their use. Where, however, wrought-iron pipes are preferred for the sake of the less immediate outlay, or for other reasons, their periodical renewal should be systematically carried out. The cost of doing so would be amply repaid by the diminution of leakage.

As gas companies seem to be more than ever liable to be mulct in heavy damages in cases of accidents resulting from the escape of gas, on the plea of their failing to adopt all "reasonable precautions" against such escapes, it may, perhaps, not be out of place here to consider whether it would not be desirable to revert to the good old-fashioned practice of fixing a tap in the service-pipe, just outside the consumer's premises, to be enclosed in a cast-iron cylinder with moveable top, like a small syphon cover. In case of fire, these stop-cocks would be of great advantage. The difficulty with them hitherto has been their liability to set fast; but cast-iron cocks are now being made, the plugs of which are faced with white metal that are said to effectually prevent their sticking.

The Wood Street fire some years ago showed how careful men ought to be in laying services, especially where the main happens to be in close proximity to buildings. That calamity, as is well known, led Mr. Upward,

of the Chartered Company, to devise a drilling apparatus for the mains, to prevent any escape during the operations of drilling and tapping, and while the service-pipe is being laid; but it may, perhaps, not be so generally known that he has recently much improved it, it being now apparently a very perfect machine for the purpose intended. There need be but little loss of gas, even with the ordinary modes of drilling and tapping, if but moderate care be taken; but Upward's improved machine is, I understand, guaranteed to prevent any escape whatever, which is certainly an advantage where services have to be laid in confined situations, not so much for the value of gas saved, as for the immunity from the risk of fire and explosion.

In addition to the various losses and liabilities of gas companies incidental to the distribution of their gas, one or two of which have been referred to, those companies that supply districts with varying levels are subject to the extra loss by leakage consequent on the excessive pressures continually on the pipes in the higher levels of their districts, and which it is impossible to prevent by the governors at the works. Formerly the only means available of reducing this excessive pressure, when it was attempted at all, was that of fixing ordinary governors in the mains in these elevated positions, but that, owing to the principle of the action of the ordinary governor, was but a partial remedy. The governors had to be weighted or otherwise adjusted, to give the maximum night pressure at their outlets, which was, of course, maintained all the twenty-four hours round. To Mr. Brothers, of the Blackburn Gas-Works, is, as far as I am aware, due the credit of having first attempted a more effectual solution of the difficulty, by the ingenious self-acting modification of the ordinary water governor, recently invented and patented by him, the object being to increase and reduce the pressure at the outlets of these supplemental or district governors, as it is increased and reduced at the works.

This is a matter that has also occupied my attention ever since I have been connected with the Crystal Palace District Gas Company, the levels of a great portion of that company's district being between 200 and 300 feet above the level of the works, and the pipes consequently under a constant pressure of from 2 to 3 inches. My efforts to devise some simple and certain means of controlling this excessive and wasteful pressure have been very successful, and the self-acting governor which I have the pleasure of introducing to the notice of this meeting, has been satisfactorily proved, both experimentally and practically, to completely answer the purpose intended. It is simply a small dry governor, in cast-iron case, and, as the object to be attained is just the reverse of that effected by the ordinary governor, the conditions of the ordinary governor are reversed to secure the end desired. The purpose of the ordinary governor is to convert a variable inlet into a *constant outlet* pressure. The purpose of the governor under consideration, on the contrary, is to give a *variable outlet* pressure—a pressure which, though reduced to the extent desired, is yet proportionate to that on the inlet, which is effected by the following arrangement:—The outlet of the ordinary governor is made the inlet of this one, to enable the inlet pressure to freely exert its force under the diaphragm, and the position of the cone, you will observe, is the reverse to that in other governors, by having its apex turned downwards. Increased pressure on the inlet, therefore, instead of contracting the gas passage, by raising the holder or diaphragm, as the case may be, and thereby drawing the cones closer into the circular opening, as in the ordinary governor, in this case raises the diaphragm, and so lifts the cone out of the opening, and consequently enlarges the gas way, the cone again falling and diminishing the passage as the inlet pressure is reduced. The cone, spindle, and diaphragm are counterpoised by a lever and an adjustable weight, and by means of these any desired reduction of the inlet pressure is effected. As the space above the diaphragm is air-tight, and is in connexion with the outlet, it is impossible for the cone to fall and close the gas passage, in the event of a sudden and unexpected draught on the main, as it would be liable to do if it were vented into the atmosphere, because the outlet pressure, which is the governing pressure, by exerting its force above the diaphragm, would in that case be withdrawn to the extent of such draught, and the pressure on both sides of the governor would for the time be in equilibrium. The governor is thus constructed on correct principles, is exceedingly simple and reliable, and when once fixed requires no further attention. I, therefore, believe that its introduction will be of advantage in enabling gas companies to control the pressure in the higher levels of their districts, and so help to diminish the item of leakage.

The Chairman: I think some gentlemen present, who are connected with the supply of gas in very hilly towns, can give us some useful hints, from their experience, as to the regulation of mains so as to diminish leakage.

Mr. H. P. Stephenson: On the question of leakage generally, I may say that this is a subject to which I have given some consideration for several years. It is a very important question, and I think that many means might be adopted which are not usually adopted to endeavour to reduce the amount of leakage. For instance, in testing pipes the general rule is to test them under water pressure, but I have found myself in many cases that pumping air into a pipe sunk in a trough of water is a very much more severe test than a hydraulic pressure of 300 feet head of water. In many cases I have thus been able to detect small holes—pin-holes—which have passed the water pressure, and so prevented the use of an unsound pipe. Again, I think after the pipes are thoroughly tested in this way, or some other, that they should be heated and tarred over. In laying services in a new town I think leakage may be easily avoided, because we all know that leakage does not take place from the joints of the mains themselves, but from the connexions of the service-pipes to the mains, and in the joints of the service-pipes. This leakage may be avoided in the first place by putting T-pieces in the main wherever you know a consumer is to come upon it, and afterwards you may avoid it in the way suggested by Mr. Cathels, that is by laying in a saddle socket instead of tapping the service into the main. I think in rural districts, and where there is not a large amount of heavy traffic in the roads, the practice of laying cast-iron services is one that ought to be carried out. The other point which I think ought to be attended to, and I have been connected with a good many companies who have failed to attend to it, is this: particular attention ought to be paid by gas companies to the removal of old services. I have examined some which, to my great surprise, I have found have been down for 20 or 25 years. Whatever question there may be about the life of a service-pipe, there can be none that in that time, even in the most favourable soil, it will become rotten and leaky.

Mr. Young: The question of leakage is one of very great importance, and one upon which the dividends of a gas company considerably depend. The result of my observation is that leakage is largely attributable to defects in the jointings of the mains. There are two distinct methods of jointing adopted in various towns—the one is by the use of the spigot and faucet end, the other by turned and bored joints. I remember an observation once made by the late Mr. King, of Liverpool, who had used turned and bored joints throughout that town. He said in ordinary spigot joints you might have minute leakages which could not be observed, and might continue for years to create leakage to a considerable extent, but with turned and bored joints you will be pretty sure to have the whole of the joints sound, and if there is any leakage it will be from defects in the pipes themselves or breakage of the socket, and that leakage would be so large that attention would be drawn to it at once, and it would be remedied. I had an opportunity a year or two ago of testing the source of leakage, by experiment on a large scale, in a case where the dividend of the gas company had been materially affected by a considerable amount of unaccounted-for gas. I divided the district into distinct portions, and cut off the branch mains into each particular portion, so as to supply that part through one trunk main only—say a district of 8 or 10 streets, and 2 miles of main. Having cut the 6-inch main in two and stopped the ends of it, I placed over it a 100 or 200 light meter, and connected it so as to supply the district through the meter, having an average pressure of 12/10ths during the whole of the day. I sent the inspectors round to see that there were no lights in the bakers or other shops to interfere with the experiment I was making, and so the index of the meter showed the extent of the leakage on that two miles of main. I found it amounted to $1\frac{1}{4}$ million cubic feet per annum for each mile of main, supposing that leakage to be continued at the same rate all the year under a 12/10ths pressure. The first thing I then did was to examine and set up all the joints in the mains. After that was completed I attached a meter again, and found that two-thirds of the $1\frac{1}{4}$ million feet leakage, or about 830,000 feet had been saved. Then I had the service-pipes looked to and repaired, the effect of which was to save another 300,000 feet. I then had about 130,000 feet of loss per mile per annum to be accounted for. To ascertain where this was, I sent the inspectors round to the consumers, who found that in many cases the joints of the meters and main-cocks of the meters were out of order, and when these were set right I had removed a very large proportion of the remaining loss. My experience, I am aware, does not agree with that of our chairman, who told us yesterday that the leakage was not from the joints of the mains. Perhaps where the mains are thoroughly well laid it may be so, but my observation certainly convinces me that turned and bored joints will get rid of a great deal of the leakage of a gas company.

The Chairman: It will be interesting just to mention that in Nottingham all sources of leakage are just about a thirtieth part per mile of main of that which Mr. Young has spoken of—*i.e.*, all the unaccounted-for gas. Mr. Loam is here, and can give you the actual figures.

Mr. Loam: I have not the exact particulars with me of the experiments that were made, but I know it is a most insignificant amount—almost nothing. I think there was one length we laid, of 4 miles, on which the leakage in 12 hours was 125 feet.

The Chairman: That was a new main laid with lead joints, but very narrow. They make them now with very much less lead. We know that, taken as a whole, there is some 12 per cent., and in many years, 14 per cent. of the gas you manufacture disappears as unaccounted-for gas, but it has not leaked away from the main.

Mr. Anderson: I have had to pay some attention to this subject, and should like to give a little of my experience. I laid a 14-inch main last year, for about 700 or 800 yards, with turned and bored joints. We tested it with 6-inch pressure, having a small portable gasholder with us, as we proceeded in our operations from day to day. The first two days work were done before the gasholder had been brought to the street. When it arrived, and the 6-inch pressure was put on the main, we found there was some leakage. We tried to discover where it was, but could not for a while till we poured water over the main, when at little spaces here and there the gas bubbled out. These leakages were repaired, and by the time we had finished the job, we were quite able to have the 6-inch pressure on the main without the slightest escape. In fact, we did not rest till we had found out every part of the leakage. These mains were laid with turned and bored joints, with a little resin and tallow round the joints. With respect to lead joints, I have had to examine many old mains, and my experience of those joints is, that it is mostly imperfect work. You come, sometimes, to a joint where there is no lead at the bottom, and there there is leakage. You come to others where the pipe has been turning a corner, and there the lead is all on one side. On the whole, I prefer turned and bored joints where I can apply them—*i. e.*, where I have straight lines, no heavy traffic, and sufficient depth to prevent the temperature of the atmosphere varying the pipe's length and splitting the sockets, which I have sometimes found to be the case from the mains being laid too shallow. With respect to the laying of services, I think, as a rule, we are far too careless in that operation. In a great many places where I see the work done there is very little attention paid to it, and the service-layers do it without any examination. Service-pipes are laid in the ground very frequently just as they come from the manufacturers. I make it a rule that all service-pipes, as soon as they come into the works, should be put into a dry store, and as soon as possible tarred or painted two or three times; they are then ready for use. The drilling of the mains is another thing very carelessly done. We employ a diamond-pointed drill, and at the end of the operation a lump of the main is split off, so that we get only one or two threads on that part of the pipe though in other parts there are five or six. There are various modes of drilling, in some of which the drill is kept constantly to its work by a spring, so that you get a hole

with a screw through the entire section of the pipe. With respect to cast-iron services, in Scotland they are always used. I do not know with what results as far as leakage is concerned, but we know that cast iron lasts only a short time. I think the association is much indebted to Mr. Cathels for his communication. His remarks with reference to the governor are very important, and if he has accomplished with a dry governor that which last year was proposed to be done with a wet governor, it strikes me he has made a decided improvement, for a wet governor, unless supplied with a spirituous liquid, gets frozen in the winter, so that I think the whole profession is indebted to Mr. Cathels if he has accomplished this result.

Mr. IRONS said he happened to have a case in which the question of leakage became a question of money in this way. The Gosport Gas-Works supplied a number of Government establishments, and for the supply of three of these establishments about 1000 yards apart there was one main meter, and a separate meter at each of the three places. It was in the contract between the company and the Secretary of State that they were to be paid for the gas as delivered to the one main meter, and the Government took the risk of leakage beyond that. During the first few quarters, the difference between this meter and the three other meters was found to be over 10 per cent.; and when the bills were forwarded to the War Office for payment, instructions were sent down for an inquiry to be made as to the cause of this difference, which amounted to £40 in one quarter. The result of the investigation was to show that the main had been imperfectly laid by the contractor for the work. The main was stripped and the joints properly leaded and set up, and now the difference between the one main meter and the three separate main meters was so trifling as not to be noticed. He mentioned this to prove that with lead joints the leakage from imperfect work might be very great, whereas with good work it might be very slight. Some years ago he had a little experience with turned and bored joints, and had a considerable amount of trouble with them in this way: the soil in which they were laid was very shifty—not a firm soil—and the sinking of the soil caused the spigot end to draw from the socket, and so create a leakage. To such an extent did this arrive, that he was obliged to substitute lead joints for the turned and bored ends. With reference to the tapping of mains for services, he might mention that the Imperial Gas Company had for years adopted the method spoken of by Mr. Cathels. They had three or more bosses cast on each of their mains, so that there was a considerable thickness of iron for tapping, and the leakage in their case was very small. He might mention that when there was competition between the metropolitan companies, and several mains were laid in one street, the workmen of the Imperial Company were able to distinguish their mains by this peculiar construction. In reference to the decay of mains, he had found that in gravelly soils its progress was about equal, whether the material were cast or wrought-iron. Iron service-pipes were liable to decay by oxidation, and in some districts, owing to the nature of the soil, this oxidation was more rapid than in others. He believed that in Scotland lead services had been very much used, and were kept in a tolerably level position by being placed in trenches formed with saw-dust or sand. He was informed that nearly all the services in Paris were lead, and were protected by earthenware tubes slipped over them.

Mr. MILNE said in the autumn of last year he tried several meters in regard to their correctness of registration. He took them from the consumers premises with the water in them, and found several which registered to the disadvantage of the company to the extent of 3, 6, and 7 per cent. These he took to pieces and cleaned, and afterwards all, with one exception, registered correctly. He had no doubt that a large amount of unaccounted-for gas, was attributable to the defective registration of meters; it was, therefore, a point which deserved the serious attention of companies managers.

Mr. WARNER exhibited some pieces of a main belonging to the South Shields Gas Company, which had been taken up from the town of Jarrow since the accident referred to in the JOURNAL OF GAS LIGHTING of the 28th of May last. The main, which was of 8 inches diameter, had been laid down about seven or eight years, and was of the usual thickness. The lower portion was laid over an old sewer, between two portions of some alkali-works, and the ground, he was informed, was completely saturated with sulphur compounds in every form. The action of some corrosive fluid had produced several large holes in this main, and one Saturday night, a few weeks back, the gas company were surprised to find that the Jarrow portion of their district was in total darkness. After a considerable amount of trouble they discovered that through these openings in the main it had become flooded by the water which had risen in the sewer during the recent heavy rains, and after the water was pumped out an explosion of gas occurred, which would have been serious but for the large number of drains in the locality. Much had been said about the laying of lead services; unquestionably they possessed some advantages, but not, he believed, to the extent which some attributed to them. His own experience during the last two or three years was not such as to induce him to put them down indiscriminately. The town with which he was connected had been redrained and paved, and the company had been much annoyed by having some of their good services cut through with picks. In answer to an inquiry, he said the soil of the town was peculiar—it was called pan-ash soil.

Mr. DUNNING said perhaps he might be allowed to state the means he had been forced to take to get over some of the difficulties referred to. He had had the management of the works at Middlesborough for 20 years, and when he first went there the services were all wrought iron, the joints in the mains of lead, and the leakage between 30 and 40 per cent. One of the first things he did was to relay the service-pipes and set up the joints of the mains, and in that way he reduced the leakage to something under 20 per cent. As time went on he was induced to try the turned and bored joints, and now he never used a lead joint. The leakage was reduced to about 14 per cent. It never got much below or above that, except when they were relaying mains. Middlesborough presented a variety of soils. One part of the town was upon a sand hill, another part was reclaimed from the river, and was composed of ballast from all parts of the world brought there in ships, and another part was bog. The mains which had been taken up from the bog portion were found to be like plumbago, and he had actually cut through an 8-inch main with a penknife; that from the gravel were pitted completely through, and those from the ballast were very much the same, the action taking place more rapidly. He had been driven to the expedient of incasing all the mains in 12 inches of clay, and he feared that was the only way to prevent damage. He thought the suggestion about having ribs on the mains was a very good one for gas companies, but a very bad one for ironfounders. He was afraid it would involve an extra cost per ton, because the risk of breakage would be greater in casting the pipes from the unequal contraction. With reference to the mode of laying services, he stated that at Middlesborough he had obtained slabs of wood from the saw-mills, cut them up in strips 4 and 5 inches wide, and laid the lead service upon them. As to leakage, or more properly unaccounted-for gas, there was no doubt a great deal was attributable to defective meters, and also to a supply to the public lamps beyond what was contracted for. His own impression was that the mains got more than their fair share of blame in the matter of leakage, as there were many other sources from which it arose.

Mr. ALLAN asked what precaution Mr. Warner had taken to prevent a repetition of the accidents to his main.

Mr. WARNER said he had simply cut out the defective pipe, and relaid another for the present, as it was intended to remove the 8-inch main shortly, and substitute one of 15 inches capacity. He should then adopt a plan similar to that spoken of by Mr. Dunning, and well protect the main with clay. With respect to services, he purposed in future using coarse brown paper, dipped in well-boiled tar, which would be wound spirally round each service, and thus protect them from the action of the soil.

Mr. ANDREWS thought there was another source of leakage, or unaccounted-for gas, which at the present moment had been overlooked, and that had reference to the supply of the public lamps. He believed contracts were sometimes entered into with local authorities and public bodies to supply 4 and 5 cubic feet per hour, and that burners were supplied by gas managers quite irrespective of the quantity of gas they would consume. In some instances, when he took the management of the Swansea works, he tested burners which ought to have given 4 feet per hour, and found that they gave 5, 6, 7, or 8 feet. This state of things had been corrected by the use of regulators. He also thought that the supervision of meters was a very important duty to be performed. In looking over the ages of various meters, he had known instances in which they had been in use for 20 and 25 years. If managers were to inspect their meters, and make renewals every 12 or 14 years, a great deal of the loss to gas companies, now attributed to leakage from mains, would be avoided. Meters which were made 20 years ago had not any of the improvements which were now introduced in their construction, and it was unreasonable to expect old meters to perform their duty as accurately as new ones. With reference to the jointing of mains, he thought it would be well where lead joints were used that the sockets should be made longer, so that in case of the sinking of the ground in which they were laid there would be less chance of the spigots being drawn out. But unfortunately it was too much the habit of gas companies to look exclusively at the economical side of the question.

Mr. WARNER would add that not only would it be well to look to the respective ages of the meters, but to give very careful attention to the sizes employed. He had known meters with 13, 14, and 16 lights upon them, while the badge showed that they were only intended for two or three. This was often the case with small meters put up in public-houses; hence the dials made two or three revolutions in the quarter, while the simple reading of the index, as it stood at the end of the quarter, was supposed to exhibit the total consumption.

Mr. PATERSON said he was pleased with the paper and the remarks it had given rise to. He thought it the most valuable and suggestive of all the discussions that had taken place. For his own part, he felt disposed to prefer turned and bored joints, where they could be laid in straight lines. He had laid several miles of mains of late years, and in every instance had used turned and bored joints. He thought the principal cause of leakage was to be found in the ill-made socket joints. During the last three years he had taken up no less than 2000 services; all of them were of malleable iron, and in many instances they were totally destroyed. He had thus been able to reduce the leakage considerably, and it was now below 10 per cent. The services he now laid were pure lead, and the joint was formed with a brass coupling, to which, when connected together, the female portion formed an end upon the service. In screwing up the female coupling upon the connexion, he formed a flange upon the end of the service, which was perfectly secure and tight. His experience was that the duration of such services was almost everlasting. He had had experience with iron services, but he found they were not to be depended upon. Under ordinary circumstances, they would not last more than eight or ten years.

Mr. COCKEY thought it would be of very great service to gas-mains if they were treated like water-mains. It would add but little to the cost, and would render them much more durable. He agreed in much that had been said about the lead joints. If they were carefully made they were as good as any could be, but it all depended upon that. Unless the road was very straight it was difficult to use turned and bored joints. He had frequently used bosses for attaching services. With an 8 or 10 inch main it was not difficult to make a good joint by tapping into the pipe in the ordinary way, but if there was a large service to be put on there was a difficulty about it.

Mr. WILLIS said last year he had occasion to take up a main which

was laid in a sandy soil where the ground was under water, and when taken up he could cut holes in it with his penknife. He agreed with Mr. Anderson that great damage was often done to mains by drilling them for services. He had found that much of the chance of this was avoided by having the drill very small. The drill for an inch pipe was not more than half an inch diameter, and its use was followed by a rose bit, well tapered and well fluted, which cut the hole very regularly, and entirely got rid of rough surfaces.

Mr. Fraser said the subject brought forward in this paper had been so thoroughly ventilated that he had very little to add. The only matter which occurred to him was the mode of casting the pipe. In specifying for a given weight of pipe, in every case it should be provided that the pipe should be vertically cast. This he believed was a very important element. During the last year he had laid down three miles of mains, from 10 to 16 inches, and without putting on many additional services, he had thereby reduced the leakage about 4 per cent., so that he thought it was clear they must take other things into consideration. He should certainly give the preference to lead joints, and by reduction of pressure he thought the leakage account might be much reduced.

Mr. Methven said the cause of bad lead joints arose in many cases from handy men on the works being employed to make them instead of thoroughly skilful hands. False economy in gas-works often induced a great deal of leakage. Companies were sometimes obliged to buy that service-pipe which was cheapest irrespective of the weight or quality of the iron. Last year he was in conversation with a gentleman of great experience in these matters, who told him that his practice was to buy none but steel pipe, of a specified weight, and that he had relaid all his services with considerable advantage. He (Mr. Methven) had followed the example, and done so to his entire satisfaction. With reference to the supply of gas to the public lamps, there could be no doubt it was often much larger than the companies contracted to give. He had seen public lamps in one town which consumed 6¼ cubic feet per hour, and in another town 7 feet per hour. He thought they were much to blame for this, and that means should be taken to remedy the evil. The public lamp-posts were constructed on very bad principles; they were very unsightly in appearance, and threw a great shadow on the ground near them. It was desirable that gas managers should pay more attention to these matters and adopt regulators. The public would be much better satisfied and the company would receive more profit.

Mr. Douglas (Newcastle): When you say "turned and bored joints," are they turned and bored? I believe some are never turned and bored except in the invoice—only scraped round. For myself I give the preference to lead joints.

Mr. Loam: The president requested me to furnish the particulars of some experiments made to test leakage in mains laid in this district. I have now those particulars with me; they are as follows:—

*Statement of the Loss by Leakage and Condensation in the Mains laid for the Supply of Stapleford and Bramcote.*

From 6 p.m., Nov. 16, 1864, to 6 a.m., Nov. 17, 1864.

| | |
|---|---|
| Index of meter—Nov. 16 | 62,800 feet. |
| Do. do. Nov. 17 | 63,000 ,, |
| Loss | 200 ,, |
| Length of mains, 6585 yards | 3·74 miles. |
| Average loss per hour | 16·6 feet. |
| Average loss per hour per mile | 4·5 ,, |

*Statement of the Loss by Leakage and Condensation in the Mains laid for the Supply of Hucknal Torkard.*

From 6 p.m., April 6, 1865, to 6 p.m., April 7, 1865.

| | |
|---|---|
| Index of meter—April 6 | 020,885 feet. |
| Do. do. April 7 | 021,470 ,, |
| Loss. | 585 ,, |
| Pressure on mains—Maximum | 22/10ths. |
| Do. do. Minimum | 11/10ths. |
| Do. do. Mean | 15/10ths. |
| Length of mains, 9756 yards | 5·54 miles. |
| Average loss per hour | 24·1 feet. |
| Average loss per hour per mile | 4·4 ,, |

These tests were taken with a water-meter under inch pressure. The mains were all laid with lead joints.

Mr. Rafferty said in Manchester for the last 20 years they had not made a lead joint. In the course of the large renewals which had taken place, they had found the lead joints so defective in many instances that the soil around them was impregnated with tar from the leakage, so that they came to the determination to discontinue their use. Generally speaking they used turned and bored joints. Plans were prepared for the contractor, and he was also supplied with gauges, duplicates of which were kept in the works, and when the pipes arrived they underwent a test, first with the gauges and afterwards with a proving-machine, with a pressure of 150 feet of water to the square inch. They were also subjected to another test after being laid. For many years he had tested the pipes after they were laid, at the ordinary pressure of 12 inches, and they had generally been found to answer very well. Where they could not make use of turned and bored joints, they made their joints with iron borings. These were mixed with 2 ozs. of salammoniac to the cwt., and some joints made in that way 35 years ago were as good now as when they were laid down. In fact, they were identically one and the same with the metal, and it was as difficult to separate the joints when properly made as if they were of cast iron. The mains laid during the last 18 or 20 years were generally laid under the footways, which was found to be a great advantage, and he strongly recommended this course after considerable experience in the matter, as if there happened to be leakage it was immediately detected. The service-pipes were also required of shorter length. These service-pipes underwent a close examination, and they were painted with oxide of iron by men specially employed for the purpose, before they were sent out. Upon most of the service-pipes they had the taps to which allusion had been made, and a great saving to the city of Manchester had been made in that way, as when a person left a house a man was sent down to turn off the tap. With regard to the public lamps he did not think they had much reason to complain of leakage. The subject of meters was quite a new thing to him, but it should have his special attention during the next year. He might state that all their service-pipes were laid by men of experience—men who had been taught to do it, and in no case would they allow a man to lay a service or make a joint who was not fully qualified. The city of Manchester was divided into districts, over each of which there was an experienced foreman. The result of the care bestowed in laying mains and services had reduced their leakage to about 10 per cent.

Mr. Brandwood said he found the leakage when he went to his present works about 40 per cent. He put up meters in different parts of the district, and found the per centage of leakage from the mains was very small indeed. He then gave his attention to the services, and found a greater proportion; but the chief cause was discovered to be with the meters. No doubt the leakage in services varied in different places, according to the nature of the soil in which they were laid; but if more attention were given to the meters and the consumption of the public lamps, he believed the great source of leakage would be avoided.

Mr. Cathels said he was aware that it was the practice of the Imperial Gas Company to have a boss cast on their mains, as he had seen them laying such pipes. But there was this disadvantage, that having only one boss instead of two necessitated the use of a quadrant. He thought it was an improvement to have bosses cast on both sides. With reference to the supply of gas to the street-lamps, he remarked that in his district, which was hilly, by the adoption of regulators they had obtained great uniformity in the flames throughout. They also found it advantageous to use regulators for the consumers, on account of the different levels.

The Chairman said this was a question in which for many years he had taken a great personal interest, and therefore he would venture to occupy five minutes of the time of the meeting. In the first place, he would draw attention to a very general objection to the statement of the admeasurement of leakage by per centage. Though good for any particular work, it was delusive when employed as a means of comparing different works one with another. He thought he gathered from one of the gentlemen present that some time ago his leakage amounted to about 20 per cent., and that recently he had brought it down to 14 per cent. But the gentleman did not tell the meeting this, which was also the fact, that he was now passing one-half more gas through the same mains than he did formerly, and consequently the admeasurement, estimated, as stated, by a per centage, did not necessarily represent a diminution in the actual amount of leakage, but only a diminution in proportion to the quantity of gas made. He hoped, therefore, that when hereafter they had statements made that the amount of leakage put into per centage was so much, they would also have another mode of measurement given, either per mile of main through which the gas passed, or in some other more reasonable manner. Now, there was an instance of what he meant in the town of Nottingham. The leakage was almost precisely one cubic foot per minute for every mile of main, and that was a thing which need not be reduced to any per centage whatever. If hereafter the company passed twice as much gas through their mains as they did now, they would still only expect to lose one cubic foot per minute upon each mile of main, and therefore their present leakage of 13 or 14 per cent. would appear to be only 6 or 7 per cent. In that event the statement would be a perfect delusion. And he would also draw attention to a further point. He knew by experience that many of these statements respecting leakage were erroneous in another particular; they were made by comparison with the station-meter, whereas nine station-meters out of ten were not correct. In the majority of cases the station-meter, oddly enough, had got a habit of travelling too fast, probably from an inherent disposition to represent a very good make. But whatever per centage in excess was put upon the manufacture of gas by the station-meter, became a source of error of equal amount when they came to estimate leakage; and if the station-meter travelled 2, 3, or 5 per cent. too fast, the estimated leakage was represented as that much greater than it really was. It might be all very well for the person making the gas to show a good make, but then the superintendent out of doors got into difficulty afterwards, because he was not able to account for the loss of gas beyond the works in the course of the year. He would therefore recommend every gentleman who was interested in the question of what the real amount of leakage was, to see at the outset whether his station-meter was right or not. Then, again, they were in the habit of estimating the leakage entirely as gas passed through the mains, but they measured the quantity made before it went into the gasholder, taking, in general, no heed of the question of temperature, and it specially happened, in that part of the year when they were delivering the largest portion of gas, that its temperature when it went from the holders was much less than when it was measured by the meter. Consequently there was 1, 2, or 3 per cent. in the winter time lost in account, though not lost in reality, in that way, which when estimating leakage by per centage was a very serious consideration. Then he came to speak of the mains, and here he would say that according to his experience it did not matter much whether they had the best form of turned and bored joints, or whether they had lead joints well made. In either case the leakage upon the mains would be almost next to nothing. It was not worth consideration in the first instance, but with reference to the question of how far these joints became deteriorated by the many accidents to which mains were exposed in the streets (not only by the shaking of carriages, which he thought had not much to do

with it, but by the opening of the ground for sewerage and other purposes, which disturbed the soil in which the mains rested and thus occasioned leakage), he certainly, as the result of experience, rather preferred well-made lead joints. They were more elastic, and would bear that sort of ugly pressure better than turned and bored points. In such a place as Liverpool or Manchester, and probably in Nottingham, where there was a basis of sandstone rock not immediately reached, at the place where the joints were made there was comparatively less disturbance, and in these places turned and bored joints would answer very well. They were, however, not used in Nottingham; but in Liverpool they were used extensively and successfully, although it was not a success which, indicated by their per centage of leakage, offered any advantages over the lead joints elsewhere. The Liverpool leakage, though not large, did not differ materially from the leakage of other towns where a considerable quantity of gas was passed through the mains. With reference to services, he was sure that both in the connexions as ordinarily made and in the corrosion of the services themselves the gas companies suffered considerably. He did not believe the leakage from mains exceeded 2½ per cent., indeed he very much doubted whether it was so much, and with regard to transpiration, he was quite certain that through iron there was no loss of gas whatever in that way. There were plenty of opportunities of testing this by putting a few inches of water over the mains, and then a very heavy pressure of air within them. This had been done, and without any bubbles coming through the metal of the pipes. They were therefore justified in inferring, as indeed they would be from other causes, that there was no loss by transpiration. If a main were well laid it might remain for 20 years underground without the soil becoming in any way discoloured. It was only when badly laid, or when the ground became disturbed by the laying on of services, that they gave rise to leakage. In such cases the soil was discoloured, and then people imagined there had been an escape through the metal. But as the result of very definite experiment, he could assert that sound iron was incapable of passing gas through it; he did not believe a single particle of gas could pass through in a year. But there were two points beyond the mains and services where the gas companies sustained considerable loss—viz., at the public lamps by over consumption, and at the meters of the consumers. In the town of Nottingham they had adopted a perfect system of supply to the public lamps by meter, and he had before him at that time the record of the last quarter's and the last month's consumption. He would hand it round for inspection, and the members would find with what complete satisfaction the supply to those lamps was taking place. He had no doubt that the gas company would save in their leakage account something like 3 per cent. by knowing precisely what gas went to the public lamps. The commissioners, who found their own lamps and managed them themselves, now paid exactly in the same manner as private consumers—they paid for the actual consumption of gas by meter indication—and both parties were satisfied. The gas company had even more reason to be satisfied than the Lighting Committee. The Lighting Committee paid for less than 5 cubic feet per hour, burning, each lamp, only 4¾ feet, while the company, who formerly delivered 6 and even 7 feet per hour without giving any satisfaction, were now paid for all they delivered. That, again, would tell very much upon what was called leakage, but which, in fact, was not leakage. Then with regard to meters, the custom in Nottingham was to employ wet meters. The company considered that the water, which practically formed the valve of a wet meter, was much safer than any slide-valve attached to another description of meter. They, therefore, used only wet meters, and those meters were always examined twice in every quarter. They had a book in which the registration was recorded, so as to indicate year by year what was the consumption in each particular quarter, and by glancing at the columns of that book, and comparing the consumption from time to time, they could generally tell when a meter was out of order. All these meters belonged to the company; they had an enormous number, somewhere about 17,000, as they supplied gas to the working classes to a very great extent. They had 6000 customers who did not pay 6d. per week for their gas, and therefore it was necessary to take care not to waste gas in these numerous small meters. But by this system, and by the exercise of great care, they got on extremely well, had no excessive leakage account, and all matters between themselves and their customers progressed satisfactorily. Every gentleman present would have his own view as to the best mode of meter management, but he thought all would be interested to know what this company did, and how they succeeded.

Mr. Paterson inquired what the proportion of meters was to the whole of the public lamps.

The Chairman said 1 in every 12. But there was a very curious circumstance in connexion with this arrangement which would probably excite the risibility of the meeting. The gas company proposed to the Lighting Committee to have 1 in 20; they had the opportunity of taking a larger quantity, but, oddly enough, they would not have 1 in 20 because it was proposed by the company, and so they chose to have 1 in 12. They had a very peculiar meter made purposely for them, which differed materially in construction from the ordinary meter. They had passed through the winter without being impeded by the frost, having given the meters a dose of methylated spirits which kept them quite lively. What he desired to call attention to, and impress upon the members, was this—because it was a subject which agitated the public mind—that if the companies with which they were connected should be required to supply the public lamps by average meter indication, they might undertake to do it without any apprehension that the companies would suffer. The thing was simple enough; no doubt it gave some little trouble, but the saving in which it resulted to the gas company, was obviously so large that he believed it would be a very good thing for them not merely to adopt it when it was forced upon them, but to do it as had been done in that town, by forcing it upon the other parties.

Mr. Paterson inquired whether the public lamp meters in Nottingham were constructed on the compensating principle.

The Chairman said they were not, as that would introduce another complexity. It was a thing good in itself, but very ill-adapted to be put under ground. The cost of the meters was about £2 5s. 0d. each. The pressure on the mains from the commencement of lighting the public lamps varied, but the adoption of governors made them completely independent of the irregularities of pressure, because they brought the pressure at the burners always to 6/10ths. The pressure in the mains varied up to 2½ inches, but the company did not care about that, as the pressure at the burners was always the same.

Mr. Warner presented the following paper, which for want of time it was agreed should be taken as read:—

## THE VALVES OF PURIFIERS.

Upon the subject of this paper, as with other portions of gas apparatus, a considerable difference of opinion has existed as to the principle of construction. The water-joint was so ingeniously applied in the earliest days of gas lighting, and was so efficient, while attempts at improvement were so frequently failures, that it is not surprising the able and experienced in the profession should have clung with much tenacity to this principle. Even now, what attraction there is to the youngest amongst us in the valvular adaptations of the water-joint, in which the principle has been so beautifully elaborated. Look for a moment at it in its simplest form, and see how much there is to admire in a long range of hydraulic main, with its scores and scores of dip-pipes, each a self-acting valve with the most delicate action and with the dirtiest of work to do; always in action, and never out of order; freely allowing every bubble of gas to pass through, and yet effectually preventing a breath to return. Again, see the principle in its higher development—the drum or wheel of a wet meter in action—and dwell for a moment on the ease, the accuracy, the simplicity of the machine performing its duties, as Rutter beautifully says, "with an impulse less powerful than the breathing of a new-born infant, and with the fidelity of a tried servant and the accuracy of a skilful accountant." So with the hydraulic valve proper—how simple, and yet how efficient, either as a stop or change valve; and what an amount of ingenuity appears to be concentrated in the centre-valve. What better could have been devised for construction or working when our manufacture was indeed in its infancy?

While thus dwelling, however, upon the beauties of the principle and its invaluable services to the fathers of the profession, we must not overlook its weak point and forget that there is nothing so unstable as water. However valuable it may have been, or even is now (and it ever will be in some portions of the apparatus), yet if its strength is weakness, and this may be obviated in the valves of purifiers without any change in the *action*, and but a slight modification in construction, there cannot be a question as to the advantages of the alteration; though this principle, that was absolutely essential 40 years since, is now none the less effective, or incapable, as we shall see, of further development. As with the wet meter, so with the centre hydraulic valve, both for many years were deemed perfect machines, but both have been further elaborated; though there is this difference between the two, that by no amount of ingenuity can the fluid be dispensed with in the meter, but with the valve a modification in the construction—indeed, with an alteration only of the old valve—it is possible to obtain the same mechanical action and all the advantages of the valve without the employment of a fluid.

In the second edition of "Peckstone on Gas Lighting," 1823, it is said that Mr. Reuben Phillips, of Exeter, was the first person who obtained a patent for an apparatus for purifying coal gas by means of *dry lime*. . . . "The vessels," Peckstone says, "are generally square, and constructed of cast-iron plates. It requires *two* of them for every establishment, in order that when the lime in one vessel becomes so impure as to be no longer able to deprive the gas as it passes over of the sulphuretted hydrogen, by the action of the *valves* attached to the apparatus the communication of the gas to that one may be shut off, and a communication opened to the one containing the clean lime. Thus there is continually one in action ONLY *at one time*, and whilst that is so the impure lime is removed from the other, and a fresh charge introduced to be ready for use." In the next edition, 1841, after describing again this arrangement, he says: "The dry lime purifiers which we have described will answer very well in small works, but in large establishments much space would be occupied by such purifiers when of sufficient power to effect the purification of the gas generated, for in works of magnitude ranges of purifiers of considerable extent would be required, in order that one range might be employed whilst the other was undergoing cleansing and recharging, in precisely the same manner as was the case when but two purifiers were used. To obviate this difficulty, a dry-lime purifier was invented by Mr. John Malam, of Hull, for which he obtained a patent in 1823."

Those who are familiar with the inventions of Clegg, and appreciate the value and beauty of those inventions, and have a due regard for the profession of which he is the father, must ever cherish his memory and honour and reverence his name; but above this there is a duty we owe to all following the same pursuits, even to the humblest in the profession—it is to zealously guard the little honour that may be due to his name. Now, it is to be regretted that this has not been done by the Cleggs—the plural is used, for we cannot do otherwise than associate their names in "Clegg on Gas Lighting"—and there the name of John Malam scarcely finds a resting place; in truth, it does not, for in Clegg's own editions it is "Mr. *James* Malam to whom Clegg was indebted for the bent inlet-pipe," or spout of the wet meter; and the admirable and scarcely less valuable invention of *John* Malam—the purifiers and centre-valve as in use at the present day is not once alluded to. It is true the advantages of a centre-valve are set forth, but it is not a centre-valve that is shown and described—it is simply a *change*-valve, by which a current of gas may be directed into either of *two* ways. It is the arrangement of Phillips, with a change-valve adopted instead of the single valves originally used—the arrangement which has just been shown by the extract from Peckstone to be defective, though this was published a month prior to Clegg's work; and even in the second edition, 1823, this invention of Malam was noticed, though his wet purifiers were principally dwelt upon by Peckstone. This want of ingennousness on the part of Clegg is the more remarkable, as he complains of being unfairly dealt with himself in this same subject—purification—by Dr. Henry, who claimed as his own idea the use of *lime water* for the purification of gas from sulphuretted hydrogen, after having been consulted by Mr. Clegg while experimenting on the subject; and he felt much pain as well as dis-

appointment at the injustice, which was the more unexpected from the friendship that had subsisted between them.

Of valves, Packstone says (1823) "that originally gaslight companies used slide-valves similar to what are used by water companies, but such have now been *long out* of general use, and hydraulic or pneumatic valves, or combinations of both, have supplied their place." He adds "the valve seems to have undergone more changes in its structure than almost any other part of gaslight apparatus." It was, however, destined for another change. In his third edition he says: "Various descriptions of valves have been, and still are used; but, for most purposes, the ordinary slide-valve answers as well as any other." Taking, then, these quotations for our text, representing, as they do, the opinions and practice of the last few years, the general employment of the hydraulic centre-valve, and its displacement by combined modifications of it, and the slide, disc, and plug valves, let us now examine the principal arrangements of purifier-valves of the present day; not, it should be observed, as to the constructive details of each valve, but as to their relative powers in directing the current of gas passing through them, so as most effectually to meet the varied and varying requirements of the purification of gas.

Presuming upon the forbearance of the meeting, as the valvular arrangements can be more easily traced, I commence with the most primitive arrangement of dry purifiers—two vessels with slide-valves—the least number of which that can be used, it is obvious, must be four, each vessel having an inlet and an outlet that have to be opened and closed as the vessel is either in or out of action. In the place of the four valves two hydraulic ones may be substituted, each consisting of three stand-pipes, a tank for the fluid, and cover with three chambers. One of the valves would be a common inlet-valve, with its inlet stand-pipe in the centre, and an outlet on each side, forming the inlet to each vessel, as brought in communication with the common inlet by the middle chamber of the cover, the inlet to the vessel on the other side being cut off and sealed by its dead chamber; the other valve being the common outlet, the middle pipe is the outlet, and the two outlets from the vessels are the inlets to the valve. This is arranged to show, as far as possible, the centre-valve in its most elementary form, but it is simply a change-valve, and is really the half of the valve, as far as the changes are concerned, of that shown by Clegg, and therefore either arrangement may be used. But with these only *one vessel* can be worked at a time: if it be required to pass the gas through *both vessels*, two other valves, if slide-valves be employed, will be necessary to open and close a communication between each outlet and inlet of the other vessel.

By examining the diagram it will be seen that each inlet stand-pipe of the vessels has two inlets, and each outlet stand-pipe two outlets—an inlet from the common inlet, and inlet from the other box, and so of the outlets—one to the common outlet, and one to the inlet of the second box. Now, as it is obvious that when any one of these two ways is open the other has to be closed; a valve contrived to effect the double object of opening one and closing the other will considerably simplify the valvular arrangement for thus working the purifiers. The next diagram shows this, and also a liberty (for which I beg to be excused) taken with Mr. Cathels's four-way disc-valve to illustrate the principle, and show more clearly the action of this gentleman's valve than in the ordinary representations. This is the only modification of a compound disc-valve, by which the construction and action is simplified, that I am aware of having been made. It will be observed that the ordinary slide-valve might be adapted to work the same changes, but Mr. Cathels attaches great importance to the disc, or Kirkham principle of construction. The advantages of this valvular system do not appear to be so considerable when shown in the simplest form in connexion with two vessels, but it is not so when a larger number are in action; the value of the arrangement is then very decided upon this point. I give an extract from a testimonial received by Mr. Cathels from one of our respected members, Mr. White, the engineer of the Birmingham Gas Company. He says: "I have fixed ten of your patent valves to eight new purifiers erected at our Fazeley Street station, and I am pleased to say they are working very satisfactorily. The purifiers are arranged for the two first to be charged with material to take up the ammonia, the four next with oxide, and the last two with lime. The valves are fixed as shown in circular, which enable us to work one or both of the ammonia vessels; one, two, three, or the whole of the oxide; and one or both of the lime vessels. The ten valves thus answer the purpose of 24 of the ordinary slide or disc valves, greatly simplifying the connexions, and facilitating the necessary changes. Mr. George Anderson has also patented a four-way valve, or we may say cock with barrel conical, but with four ways through it instead of two, and as it has not to answer the purpose of a *stop*-cock, it has but a vertical diaphragm or partition, with conical edges and top and bottom plate, instead of the ordinary plug fitting into the conical barrel. The connexions and changes effected, are the same both in this valvular arrangement and in that of Mr. Cathels, and also in an arrangement shown upon the hydraulic principle in the working drawings and designs in mechanical engineering by Fullarton and Co. These arrangements may very properly be termed *coupled valves*, as they must always be paired or worked in couples when applied to purifiers. Thus we have *two* or *a pair* for two purifiers, *four* or *two pairs* for three purifiers, and *six* or *three pairs* for four purifiers, and so on. With four vessels the work of the six valves is thus: two to each couple of boxes, and two as inlet or outlet valves, common to both pairs of boxes, the boxes being worked in pairs by this pair of valves. It is said of this arrangement that the *whole* of the vessels may be worked together, and this is correct; but it cannot be done through *all* the changes of the purifiers and at the same time work the crude gas through the foulest purifier first and the cleanest last. This will be seen by distinguishing the four purifiers by the first four letters of the alphabet, and, referring to the diagram, showing the whole of the changes. When started, the vessels are worked in the order of the alphabetical arrangement.

A, B—C, D.

A, being thrown off, B—C, D are then in action;
A, to be last, the order is C, D—B, A, for A and B are coupled; but the [order should be B, C—D, A.
B is then put off, and C, D— A, are in action;
B is again in action— C, D—A, B;
C is the next off— D—A, B;
C, being on, the order must be A, B—D, C, which places D, the *dirtiest* [vessel, immediately before
D is next thrown off— A, B— C; [the last.
D, on being put on again, A, B— C, D, brings us through the [whole of the changes.

There is, however, it should be added, an arrangement of Mr. Anderson's, by which the whole of the vessels may be worked together and in proper succession; but it is presumed that this valve, which is also another modification of the four-way cock, is **not** so satisfactory in action as the other, as it is not shown either in the last edition of Clegg or in Mr. Anderson's pamphlet on "Improvements in Apparatus employed in the Manufacture of Gas." But, as a multivalvular arrangement, this is the most simple of any devised for a set of four purifiers, four only being required; and, as to the changes effected, nothing more can be desired. One advantage Mr. Anderson and Mr. Cathels claim that cannot be questioned—"There is not that chance of a workman making a mistake when one valve is required for *each purifier* as there is when he has some 12 to 16 valves to work, as by the ordinary valve."

The plug or conical valve has been further elaborated by Messrs. Bower and Hollinshead, and patented by them in 1863. The novelty of their invention is the making of the barrel or conical seating of the valve deeper than the plug or cone, and covering the cone with a lid, thus enclosing it, and so allowing the cone to be raised from its seat for ease in changing without permitting any escape of gas, the cone being worked by means of a screw and hand-wheels attached to spindles passing through a stuffing-box in the lid or cover. But the chief improvement is in the construction of the plug or cone; it is arranged with a shifting partition and plates in the body of the plug, by which the relative positions of the inlet and outlet may be changed, and, consequently, the number of vessels in action varied. The next diagram shows this valve. The valve of Messrs. Cockey is somewhat similar is plan, but theirs is a *flat-faced* rotatory valve, and, as arranged for two vessels, it has a centre inlet and five segmental chambers, or cells, around it—four for the inlets and outlets of the vessels and one the common outlet. The cover has three chambers—one equal to one of the segmental cells, and communicating with the centre inlet; the other two chambers are each equal to two segmental cells, so that, when the inlet chamber of the cover is in direct communication with the cell on either side of the common outlet, the two opposite cells to it communicate with each other by means of one of the large chambers in the cover, and, as these two cells are the outlet from the first vessel and the inlet to the second, and as the other chamber of the cover brings the outlet of the second into communication with the common outlet, it follows that the two vessels may be worked together; and, to throw one off, the inlet of the cover has to be placed over the outlet part of the vessel; the inlet of the vessel proper then becomes the outlet, and is then in communication with the common outlet by means of one of the large chambers of the cover, the other chamber covering the inlet and outlet of the vessel thrown off. It is but due to the inventors of this valve—the Messrs. Cockey—to say that their patent has now run nearly ten years, and that this power of working one or more vessels, which we have again to notice immediately, with the same centre-valve, by reversing the current of gas, originated with them, as far as I can ascertain.

It may be said that the extent of this power of adaptation in working one or more vessels with the same valve is dependent upon the means for increasing or lessening the number of pairs of inlets and outlets between the common inlet and outlet of the arrangement; or the variation may be said to depend upon the extent to which the relative positions of the first inlet and last outlet of the purifier—which are the common inlet and outlet—are capable of being changed. This, we may say, is the new principle introduced into the valvular arrangements of purifiers, and the simplest mechanical arrangement by which it may be most freely developed may be said to be the most useful.

The constructive details of the next valve are similar to the hydraulic valve already described—a tank, with stand-pipes, a pair to each purifier, arranged around a common inlet, and a common outlet intermediate between the two—the common inlet in the centre, and the surrounding circle of stand-pipes. The cover has four chambers, the whole being of an annular form, or nearly so. The smallest chamber is in communication with the common inlet in the centre by means of a passage connecting the two. The annular portion of this chamber is *two diameters* of a stand-pipe in length. Contiguous to this on one side are two of the other three chambers covering four stand-pipes; the other chamber, which covers two stand-pipes, would complete a perfect annular cone, but at each end a space is left equal to a diameter of a stand-pipe, separating the chamber on one side from the common inlet-chamber, and on the other from the two other chambers, each chamber being one diameter larger, the same as the inlet. Now, as the inlet-chamber is two diameters, and there is a space of one diameter between it and the single chamber, it will be seen that if the inlet is put over the *outlet* of any one purifier, the inlet *proper* of the purifier will become the outlet; and as there is the *space* on that side between the common inlet and the single chamber, the vessel is thus brought into direct communication with the common inlet and common outlet, and then ONE *purifier only is brought into action*. And again, remembering that the common inlet is equal to two diameters of a stand-pipe, and that each chamber is also one diameter larger than need be to cover any two pipes, *two* vessels will be brought into action by shifting the cover backwards, and bringing the single chamber over the outlet of the one vessel that is in action; the *outlet* from the second vessel will then correspond with the *space* between the single chamber and the double ones, the two other vessels remaining shut off as before. To bring these into action the current of gas has to be *reversed*. The inlet now becomes the inlet again instead of the outlet, and thus the gas can pass through *three* vessels, the fourth remaining off with its pipes covered by the single chamber; but by shifting this over the outlet of the third vessel the last one is brought into action, and thus any one, two, three, or four vessels with this valve may be used in the order that has now been shown. With the ordinary hydraulic centre-valve only three vessels can be in action at the same time, and the only variation that can be made by reversing the current is the working of two boxes, the other two being cut off. The modification is by Mr. James Wilson, and is certainly most ingenious, and has advantages over the ordinary valve; but doubtless many would object to the back action when only one or two purifiers are in use, and the necessarily increased diameter of the valve is a disadvantage, as it is very considerable. With the ordinary valve little more space need be left than sufficient for the sheet-iron divisional plates to pass between the stand-pipes, but in the modified form the space between all the stand-pipes must be equal to the diameters of the pipes themselves. Thus with 12-inch connexion eight 12-inch pipes could be placed almost close together in a circle, but in the modified form the circle through the centres of the stand-pipes would have to be equal to sixteen 12-inch pipes.

Before leaving the subject of hydraulic valves, I beg to draw your attention to another very beautiful modification that appears to be lost sight of in books on gas-works of the present day. It was introduced—it should be said invented—by that worthy contemporary of Clegg, John Malam. Those who have a copy of Peckstone will remember the *double cup-valve*, constructed, as he says, for "sustaining double the pressure of that with but a single cup." The arrangement, as you will remember, is an annular cup for dipping into two concentric vessels filled with a fluid so as to form a

double seal or lute, or two separate and distinct water-joints; and "it followed," so Peckstone writes, "that a valve so constructed is capable of sustaining double the pressure of one made with a single cup." In describing the construction, however, he says: "Through the bottom of the valve is brought a wrought-iron bend connected to a pipe rising to the top of the valve (on the outside), and is for the purpose of introducing water into the *inner* vessel or ring of the double cup, the outer cylinder" (please to note this) "of which, being bored near its bottom, ALLOWS the water to pass into the *outer* ring," or vessel. Now, what can be meant but that the water is introduced into the inner cup, from which it flows into the outer one, "bored near its bottom"? This being so, how can there be two seals? and how can the valve sustain double the pressure of a single cup? I have had a section of the valve made, so as to show the action, for we can learn nothing further from Peckstone, though he says "the action and counter-action of the inner and outer of the lower cups being reciprocal between each other, as must appear evident." As I do not think this explanation or description at all satisfactory. I will try to give you the principle in another way. Take the common pressure-gauge, a bent pipe or inverted syphon, in action. We then speak of the pressure of gas, in reading its indication, as being equal to *a column* of water, or *one* column of water, which the gas sustains. Now, with gas, we cannot do impossibilities, though it is often expected from us; and if we give a pressure to sustain *a* column or *one* column of water a given height, that same pressure will not sustain *two separate* columns the same height, as when two pressure-gauges are connected one to the other, the pressure of the gas but on one column and that of the atmosphere on the outer column of the other gauge, the two intermediate ones being connected, the distance between the top of the two columns and the lower surface of the gas column will be but half the distance between the two surfaces of but one column, as what we gain in power we lose in speed, and thus it is that this valve will sustain double the pressure of one with but a single cup.

Mr. George Bower is now making a dry valve upon somewhat the same principle as Mr. Wilson's, the moveable partition, as in his patented valve, being dispensed with. He has very kindly forwarded to me a diagram of the arrangement with a description of the same. "The one shown," he says, "is for 8-in. connexions; the valve-box has eight branches cast on round the upper part as shown, and two branches on the lower part for inlet and outlet, which may be at any angle to each other for connexions, but are generally placed opposite; the inlet-pipe or branch extends to the centre of the valve-case, and vertically to a level with the bottom side of purifier branches; the top of pipe is turned taper to fit the plug; the upper part of case is also bored out taper, and is fitted with a plug, which is turned and ground in tight (the arrangement of this plug is shown in diagram); the plug fits on to the centre-pipe, and has an opening leading from the centre-pipe A to the inlet division B; the outlets C C are formed by openings in the bottom of the plug, which lead to an open chamber around the centre-pipe A, and in communication with the outlet branch. The moveable diaphragm represents the plug, and by turning it to the several positions required its action will be at once seen. For instance, by setting the inlet B to the inlet of purifier 1, with the *adjoining* outlet C opposite to the branch for outlet from No. 4 purifier, the gas will be represented as going through 1, 2, 3, and 4 purifiers; and by turning it a little further, so as to bring the other outlet C opposite to the outlet branch for No. 3 purifier, the inlet division being still open to the inlet to No. 1 purifier, No. 4 purifier will then be shut off. This explanation will apply to the other purifiers when three or four of them are to be in work, the one to be shut off being always the last in the series. When two or three purifiers are wanted to be shut off the action would be reversed, the inlet B being placed opposite the *outlet* branch of the purifier or purifiers to be left in work—the gas consequently passing down hill when an outlet-box is used in the purifiers. The two last operations would, however, be seldom or never required. The valve is fitted with cover, stuffing-box, and gland; the lifting-gear consists of two pillars and a cross-bar, into which fits a hollow screw with hand-wheel keyed on; the spindle attached to plug passes through this, and has also a hand-wheel keyed on top; when the positions have to be changed the wheel on screw is turned so as to lift the plug, and the wheel on spindle is also turned to the requisite position, as indicated by a pointer fitted on one of the arms, and made to slide along it: the pointer is directed by an index-plate fixed on cross-bearer, and marked to every position required; when placed in position the screw-wheel is turned so as to lower the plug tightly into its place."

The principle of equalizing the pressure on both sides of the hydraulic valve originated, it is believed, with the late Mr. King, of Liverpool. It is upon the same principle that the Messrs. Walker, of Donnington, construct their dry purifier-valve—the enclosing of the valve cover and joint by a gas-tight box, and taking the outlet from this instead of having a concentric outlet-chamber in the valve itself, as in that of the Messrs. Cockey—the faces of the valve being flat. Upon this principle a very large one, 7 feet in diameter, is now being made for the Manchester Corporation Gas-Works, which is to be fixed in the place of the hydraulic one that was the cause of the explosion some months since. The circulation through both these valves otherwise is the same, and also the same as in the ordinary centre hydraulic valve—namely, three vessels worked in succession and one off, the changes being effected by simply moving the valve-cover round, so as bring its common inlet and outlet over the first inlet and last outlet in the series of vessels in action. Again, these valves can, as in all ordinary centre-valves, be worked backwards by having the common inlet brought into direct communication with the outlet of any one of the vessels, in which case, as there is only *one* instead of two intermediate chambers of communication between the common inlet and outlet, the relative positions of the common inlet and outlet are changed; but two vessels are brought into communication with each other, and, therefore, but two can be in action, and two will be shut off.

"I mentioned to you that we had received an order from the corporation of Manchester for a purifier centre-valve of very large size. We have re-received another order from them during the past few days for a second one, the same size as the former. The surfaces are no less than 7 feet diameter, and they are the largest scraped surfaces that ever have been made in the world. There never has been a surface of that size got up for any purpose, either in land or marine engineering. If you think proper it might be worth while stating this in your paper. It is interesting so far as the enormous size such things are being made, if for no other reason."

It will have been observed that in the whole of the centre-valve examined, with the exception of that of Messrs. Bower and Hollingshead, and that only to a limited extent, from one to two vessels, the purifiers cannot be worked in succession from the least to the greatest number in a series, with the current of gas passing through the purifying material in the whole of the vessels in the *same* direction. Or, in other words, there is little or no power to vary the relative positions of the common inlet and outlet of the valves. I have now, however, to beg for a little further indulgence, while I place before you an arrangement of my own, by which an unlimited control is obtained over the working of the vessels. Any number may be placed in a series, any one in the series may be worked by itself in the series, any number in the series may be worked from one to the whole series, and the current of gas made to pass in the usual way up through the purifying material, and always in succession from the dirtiest to the cleanest vessel. The plan of construction is the separation of the common inlet from the common outlet, and giving to each an independent action. If the body or seat of Cockey's valve be taken, the cover to it will be the same in plan, but will have one cell or chamber, and the annular chamber covered, and this forms the common inlet; the top of this inlet-cover is faced, the same as the under portion, and like it forms a seating for a cover, which is the outlet-cover, the sectional plan of which is a radial chamber communicating with the centre outlet, and three double chambers, equal to two of the ports or cells in the inlet-cover, being the chambers of communication between the purifiers, the other chamber over the common inlet being a dead chamber when the four vessels are in action, but when only three are in action it may be made a separate inlet chamber to the vessel "thrown off." This chamber, and the next to it, is supplied with a simple valve on the top of the cover, so that for ventilating purposes a large volume of air may be *forced* through the inlet of the purifier, or *drawn* through the outlet; to accomplish which in the ordinary way no less than eight separate valves are required, or their equivalent, and a large quantity of connexions to "change over." The two covers are moved together by a pinion working into the toothed periphery of the inlet-cover, but to change the *number* of vessels in action the top, or outlet, cover is alone moved by a pinion in the same way.

The principle of this valve may be applied to the ordinary hydraulic valve very readily and inexpensively, a new cover alone being required. A connexion need not be broken or made, and but a few minutes stoppage of the make is only necessary while the old cover is taken out and the new one put into its place.

Now as to the advantages of the system. It has been said that by working the four vessels an increase of 25 per cent. of purifying surface is obtained; this, however, is true only so far as the setting out of new sets of purifiers is concerned—that it to say, the question then may be whether the arrangement shall be for three or four vessels. If it be decided to have the valvular arrangement for working but three out of the four vessels, then one-fourth, or 25 per cent., of the purifying surface is lost, which might otherwise, at least occasionally, be made available; but in the case of old sets of purifiers in action it will be an increase of one-third of purifying surface, or 33⅓ per cent.—an increase that could be most beneficially used when most urgently needed, and when it would be most efficient when large and excessive volumes were passing—an increase that would assist to tide over in comfort many a season that would otherwise be an anxious and a dangerous one. But beyond this there appears to be indications of a positive gain by working the four vessels. They appear to run longer by keeping the dirtiest vessel on longer than usual, which may be done for some time after the second vessel gives a dirty test; if this be so there will be a saving of lime, and, of course, a saving of labour also. I am not enabled, however, which I much regret, to lay before the association a sufficient number of experiments to satisfactorily decide the question. There will be found also a considerable saving where the condensation is defective, the dirty vessel in such case acting, as it were, as a scrubber, and so preserving for a longer period the lime in the other vessels.

Mr. WARNER explained, by the aid of elaborate drawings and models, the nature and action of the valves described in his paper. Great regret was expressed by the members that there was no time left at this sitting for the discussion of his carefully prepared subject.

The CHAIRMAN said the next business before the association was a proposed alteration in the rules, of which notice had been given in the regular manner. The committee had considered the matter, and Mr. Goddard was now prepared to bring it before the meeting.

Mr. GODDARD said he had felt year by year that it was a very important thing for the association that the committee should be periodically changed. The association had now been in existence four years, and the same committee had been re-elected year by year. In the interest of the association, he thought the infusion of a little new blood was desirable. He, therefore, proposed a resolution to the effect—"That the committee consist of nine members, three of whom shall retire by rotation annually, and be eligible for re-election during the following year; that the president, vice-president, treasurer, and honorary secretary be elected annually, and be *ex officio* members of the committee; five to form a quorum."

Mr. BROADHEAD seconded the motion.

Mr. ANDERSON asked whether it was necessary to make it absolute that no retiring member of the committee should be eligible for re-election for a year.

The CHAIRMAN said the committee were unanimous in opinion that now the association had become so numerous it was necessary that the governing body should become more popular, and, above all, that it was essential the president should be changed from year to year; or, at all events, if the same gentleman were appointed he should reign by the good wishes of the members, expressed at their meeting, for the second year. His own opinion was, and he spoke from the experience of another society, that nothing could be more undesirable than that this association should have a permanent president, or a president remaining long in office. He felt that the president ought to be changed every year, because as they were now a very numerous body, there must be amongst them many gentlemen who could with propriety aspire to occupy the chair of the association, and who were in every respect worthy to occupy it. Moreover, they travelled from place to place, and it was desirable that gentlemen who were the managers or directors of the gas-works in the towns they visited should have the opportunity of occupying the chair on those occasions. There was another reason which was very important—in fact, more so than all—that unless they made these changes repeatedly, they would be exposed to the possibility of that which had formerly happened to another institution, that the chair might be occupied by some person who was accused of holding office as a professional job. It might be well in the early formation of the society that there should be little change, but it was not now desirable. In his opinion it was better that they should annually change their

president, the vice-president becoming president for the next succeeding year, and that the president should fall back into the ranks, to be re-elected at the pleasure of the members on some future occasion. Of course if it were their pleasure to re-elect him to the chair it would be in their option to do so, but no gentleman should occupy the chair as a right, or put the association in such a position as to make them feel that they could not make a change without giving personal offence.

Mr. PATERSON said the members of the association could not shut their eyes to the benefits they had derived by the presidency of Mr. Hawksley in time past, and they would be very slow to accept any proposition which would make any change in that direction. He entirely concurred in the other parts of Mr. Goddard's motion, but thought it would not be well to adopt any course which should interfere with the present arrangement in reference to the presidency of the association.

The CHAIRMAN expressed himself as greatly obliged by the favourable opinion entertained of the way in which he had fulfilled his duties, but, believing the course he had suggested was the right one to pursue, he could not consent, even with the good favour of the meeting, to resume the chair after the close of the present session.

Mr. DOUGLAS said although possibly he might be inclined to say more in favour of the president, he felt that the course suggested from the chair was the right one for the association. The only alteration he would make in it was to propose that the president should occupy the office for two years, so that the association might have the full benefit of the experience he would acquire in the management of their affairs.

The CHAIRMAN said if the vice-president of one year were the president of the next, the association would have all the advantage resulting from experience.

The motion was then put, and carried unanimously.

The CHAIRMAN said it had been suggested that there should be a discussion as to the amount of subscription, but the committee were of opinion that, as the finances of the association were not now in a deficient state, it might possibly be of advantage to defer the consideration of this subject for another year.

Mr. GODDARD said the alteration in the rule was suggested by him at the last meeting, owing to the proposition to print the transactions of the association, with drawings, &c.; but in committee it had been thought desirable to continue the present rate of subscription for another year, to see how the funds kept up. He should therefore withdraw the motion of which he had given notice.

After some discussion as to the mode in which the election of the members of the committee should take place, a resolution was adopted to the effect that in future years the committee should prepare and send to each member a list of twelve persons eligible for election, from which list the members would be at liberty to make a selection, or to which they might add the names of any other persons eligible to fill the office.

The several resolutions last adopted are embodied in the following rule, which is substituted in lieu of Rule No. 7:—

The officers shall consist of a president, vice-president, treasurer, secretary, and nine members of committee, to be elected at the general meeting, in the manner hereinafter directed. The president, vice-president, treasurer, and honorary secretary shall be *ex officio* members of the committee. Five to be a quorum.

The president, vice-president, treasurer, and secretary, shall be elected annually.

The president shall in no case hold that office for a longer period than one year, and at the expiration of such period he shall not be re-eligible for that office for the period of three years.

The vice-president, at the expiration of his year of office, shall be nominated as president for the following year, unless he give notice to the committee of his intention to decline accepting the office.

Three members of the committee shall retire annually in rotation, and be ineligible for re-election during the following year.

The committee shall, previous to the annual meeting in each year, prepare a list of members whom they nominate as suitable for the offices of president, vice-president, treasurer, and secretary for the ensuing year. The list shall also contain the names of twelve members whom the committee nominate as fitted to become members of the committee. A copy of such list to be forwarded to each member of the association before the annual general meeting, and each member shall be at liberty to make a selection from the list, or to substitute the name or names of any other member or members, for each respective office; but the number of names so selected or substituted must not in any case exceed the number to be elected to the respective offices.

On the motion of Mr. DOUGLAS, seconded by Mr. MARTIN, it was resolved unanimously—"That Thomas G. Barlow, Esq., the vice-president for the past year, be the president of the association for the ensuing year."

On the motion of Mr. FRASER, seconded by Mr. ANDREWS, it was unanimously resolved—"That E. Goddard, Esq., of Ipswich, be the vice-president of the association for the ensuing year."

On the motion of Mr. PATERSON, seconded by Mr. BARRAS, it was unanimously resolved—"That Henry Newall, Esq., be re-elected treasurer of the association."

Mr. GODDARD: The next resolution is one which I propose with a very great deal of pleasure. We have a gentleman amongst us who has occupied the position of honorary secretary to the association ever since its formation with great ability and zeal, and whose services are beyond all praise. I beg to propose that our esteemed friend, Mr. Blackburn, be re-elected honorary secretary of the association.

Mr. RAFFERTY: I have great pleasure in seconding the resolution.

The resolution was put and carried unanimously.

The following gentlemen were then elected members of the committee:—Mr. Geo. Anderson, of London; Mr. Methven, of Bury St. Edmunds; and Mr. White, of Birmingham.

Mr. DOUGLAS, of Portsea, proposed, and Mr. FRASER seconded, a resolution to the effect that the ex-president be a member of the committee, *ex officio*, the following year.

The CHAIRMAN said, however gratifying this proposition might be to him, he felt that it was one which he could not put from the chair, as it was in violation of the rule they had already adopted, that the committee should consist of 13 members.

On the question of the place where the next meeting should be held, Mr. Broadhead proposed Leeds, Mr. Warner proposed Bristol, but on a show of hands it was decided by a large majority that it should be held in London, during Whit week.

The CHAIRMAN announced that he had received a packet of books relating to the management of the Paris Gas-Works, which had been presented to the association by M. Emile Durand, the editor of the French journal, *Le Gaz*. He hoped that this gift would form the commencement of a library for the association, and he was sure the members would join in a cordial vote of thanks to the donor.

It was unanimously resolved—"That the thanks of the association be presented to M. Emile Durand for his present, and that this resolution be conveyed to him by the secretary."

Mr. ANDERSON proposed a vote of thanks to those gentlemen who had exhibited apparatus or read papers before the association.

Mr. FRASER seconded the motion, which was carried unanimously.

On the motion of Mr. MARTIN, a vote of thanks was given to the officers of the association for the past year.

Mr. FRASER moved, and Mr. BROADHEAD seconded, a vote of thanks to Mr. Hawksley for his able conduct in the chair.

The resolution was carried by acclamation.

The CHAIRMAN briefly acknowledged the vote, and the proceedings terminated.

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### LIST OF ARTICLES EXHIBITED.

Messrs. A. Wright and Co., Westminster, Photometric Apparatus, arranged by Mr. F. W. Hartley, to illustrate the application of the Carcel Lamp, the same as used for photometrical purposes in Paris, to the Bunsen system of Photometry.

Mr. Hutchinson, Barnsley, cabinet containing specimens of Coal, Coal-Tar Products, Coke, &c., &c.

Mr. John Ohren, Longton, model of his Improved Condenser and Scrubber.

Messrs. C. and W. Walker, Donnington, specimen of their wood Purifier Grids.

Messrs. Forrest, Liverpool, their Improved Reflecting and Shadowless Street-Lamp.

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### DINNER TO THE MEMBERS OF THE ASSOCIATION.

On Wednesday evening Mr. Hawksley entertained the members of the association to dinner at the George Hotel. The company also included the directors of the Nottingham Gas Company and of the Nottingham Water-Works Company. The dinner was served in excellent style.

After the usual loyal toasts,

The CHAIRMAN proposed the toast of the evening, "Prosperity to the British Association of Gas Managers." In doing so, he said that all present were more or less intimately associated with gas enterprise, either as directors, engineers, or managers of gas-works, or as investors of money in gas shares, or, as in the case of Dr. Letheby, engaged in the scientific investigation of the various problems connected with it. To those who formed the majority of the guests who had honoured him with their company, it was specially known how much the world at large was indebted for the investments that had been made in gas property, and it was for them to direct the use of those investments so that the persons who made them might receive an adequate remuneration for the trust they had reposed in them. For a long time past gas enterprise had been in a very different position to what it was 20 or 30 years ago. The companies had been placed in considerable difficulty; they had been subject to great local and parliamentary agitations; they had seen great reverses in the value of their property consequent upon crises in monetary affairs, and consequent upon the agitation fostered by persons who knowing something had not known enough to enable them to direct their energies into a right and proper course. (Hear, hear.) It was to an association of this kind that those who had invested their money must look in a great measure for its safety, because it was by the intelligent and united efforts of the members of such an organization that the tide which had set in in opposition to their interest, and which had certainly been very steady and very constant in its course, must be stemmed. There were circumstances which in the minds of many persons indicated that the time was approaching when the value of gas property would be still further considerably reduced. For himself, however, he did not believe there would be any permanent depreciation of the kind, although there were many things which might justify the apprehension. For example, they found that the material from which gas was manufactured was becoming day by day and year by year more expensive; they found that from causes over which they had no control, some of them political some of them social, the cost of labour was continually increasing; but notwithstanding these drawbacks to their success, there was, he still believed, a good deal which would enable them to compensate these disadvantages. By the aid of science and their united efforts they would not only be in a position to cheapen the cost of production, but by the means which had been placed before the association during the last two days, they would be able to enlarge the field from which the materials out of which light was produced could be drawn. They would also be able to realize, as he believed, notwithstanding the desponding views of his friend Dr. Letheby, who told them on the previous night how much in this respect they were dependent upon the changing fashions of the day, a greater value for those residual products which a few years ago, and even up to the present day, were treated with neglect. Besides that, they had the means of promoting many economies, amongst others by directing attention to the investigation of those circumstances which led to the enormous

stock of the material which it was their function to supply to the public. In that way they would do very much to replace the loss now sustained by the companies, by reason of the increase in the cost of coal and the increase in the rate of wages. (Hear, hear.) He looked to the future of this association as he looked on to the future of gas companies, with very great pleasure, because he felt sure that that future would be a success. (Hear, hear.) He was astonished to find that in the course of three years they had gathered in no fewer than 177 members—gentlemen immediately connected with the production of gas. When he had the honour to be appointed president, at the establishment of the association, he did not for one moment anticipate that they would ever be able to gather together more than a hundred members. They had, however, already nearly doubled that number, and, from the facts which had come to his knowledge during the last few days, he had no reason to doubt that that number would soon be raised to 250. (Cheers.) They could not do otherwise by such an association than produce good results. They debated the most interesting subjects connected with the application of science to the production and distribution of gas, and they never met without obtaining a new light. All this tended to the advantage, not only of the investors of money, but also to the advantage of the public at large. With much satisfaction he proposed, as a toast, "Prosperity to the association," and would conclude with the expression of a hope that its career would be one of continued and increasing progress. (Cheers.)

The toast was drunk with all the honours.

The CHAIRMAN said he had now to propose a toast which he was sure the meeting would receive with entire satisfaction. The association had done great honour to the town of Nottingham by visiting it on this occasion; and, on the other hand, he could assure the members that the Nottingham Gas Company were desirous to do great honour to them. They had thrown open their works to the inspection of the members, and every one present was aware how dangerous a thing it was to let knowing people into gas-works. (Laughter.) But the Nottingham Gas Company had great trust in their good faith, and in opening the works to their inspection they had submitted themselves to a criticism such as they had never heretofore been exposed. They trusted, however, that the members had looked upon those works with a favourable eye, even though some of them might possess undertakings compared with which these were insignificant both in construction and in design. With reference to the Nottingham Gas-Works, he might mention that it was now exactly 50 years ago since they first received favour from the inhabitants of the town. For more than 20 years the company struggled under great difficulties, principally because their capital was small, and because it was not at that time understood that an enlargement of capital would be productive of advantage to the adventurers as well as to the public generally. In the year 1840 they were threatened, and more than threatened, with a great opposition. At that time they had some very slow old-fashioned ways, and were quite indisposed to do more than they had commenced to do in 1817. They thought then that their small capital of £16,000 was to last for ever, and that having laid out that sum of money the public were more than bound to be satisfied. Suddenly, however, their eyes became opened. They had been for a long time asleep, and they did not wake up voluntarily; but it seemed as though they got all at once one of those tremendous slaps on the ear which Dean Swift mentioned as being incident to the state of affairs in Laputa. (Laughter.) The result was that they had a three years conflict in Parliament—a conflict carried on, he was proud to say, with great energy, and resulting at last, by a majority of one, in the continuance of the old company on a new footing. (Hear, hear). They accordingly took grace of heart, and feeling persuaded that the best way of meeting the requisitions of the public was, first, to embrace all those who had been their most bitter opponents and make them their best friends, and then to do all they could to reduce the price of the article which the consumers required at their hands. But there was the old difficulty—they had only a capital of £16,000, and how was £16,000 to meet the wants of a population then amounting to 50,000! They could not see their way at all. But somehow or other, Parliament again unsealed their eyes—and when they were opened, they were opened very wide—and they suddenly became a company with power to raise £40,000. They thought then they should never want any more money after that; but, unluckily, in their endeavours to meet the wishes of their friends, the consumers, they very soon got rid of this additional capital, and were very much surprised how and by what means they had accomplished so disastrous a result. (Laughter). However, they had some further powers—some shares yet undisposed of; and it struck the directors that if they disposed of those shares in the public market, the company then paying 10 per cent., they should be able to raise twice the nominal amount of capital which they represented. He mentioned this circumstance because it had an important bearing on gas undertakings generally. They had some small works to erect, which were estimated at a cost of £8000, and the question was, how to raise that money. These shares were therefore sold, and instead of producing the required £8000 they produced £16,000, and the company found themselves again uncommonly flush of money. (Laughter). Afterwards they had to go to Parliament, and Parliament by some means, whether on the proposition of the company or from the force of circumstances he was not prepared at the moment to say, considered it expedient to double their capital, and reduce their dividend one-half. In that way the company found themselves all at once in possession of £80,000, subject to a 5 per cent. dividend. That was the same thing with regard to the public, no doubt; of course the public could not receive any injury from that circumstance, nor was it possible for the company, so far as their interests were concerned, to be at all damaged thereby. Parliament also gave them power to raise further sums of money, so that their capital was really increased up to £200,000; but they coupled with this power a provision that all the future shares of the company should be disposed of by public auction, subject to this 5 per cent. dividend, and that all premiums received upon the sale of shares should go in the place of other capital, and should not be subject to any dividend whatever. The public entertained a high opinion of the undertaking, and were wise enough, or foolish enough, to give the company a large premium upon the nominal value of their shares. In consequence of that, money flowed in plentifully, and just concurrent with that circumstance there came an enclosure of commonable land to the extent of two square miles, the town suddenly increased, and the company's money was constantly in demand; their dividends got up in proportion, the public purchased their shares freely, and the company, having effected the operation of doubling their capital once, soon found themselves in a position to go to Parliament again and repeat the operation. (Hear, hear.) Their present position, therefore, was that they had a capital of £400,000, and the result of their successful working, so far as the public were concerned, was this, that they were able to supply gas of 17 or 18 candles illuminating power at a maximum price of 3s., and a minimum price of 2s. 9d. per 1000 cubic feet. (Cheers.) Probably in the whole history of gas companies a parallel state of things could not be found. Usually the opposite state of things occurred, and money had to be raised at a very large cost. At Nottingham it had been raised at a very small cost, so that the pressure of the dividend, which usually amounted to 1s. 6d. per 1000 feet of gas, there only amounted to 9d. The state of things therefore was wholly exceptional, and could not be, and probably ought not to be, accomplished in other places, and he mentioned these facts not in the spirit of landation, but because Nottingham had been sometimes quoted as an instance in which an abnormally high quality of gas was supplied to the public at an abnormally low price. The circumstances which he had mentioned would explain how so strange a state of things had been brought about, and how it was that that which had happened there could not be repeated elsewhere. After some further observations the chairman concluded by proposing "Continued success to the Nottingham Gas Company."

Mr. BIRKIN and Mr. BISHOP, two of the directors of the company, responded to the toast in appropriate terms.

The CHAIRMAN then gave the health of the gentlemen who had, he said, read some most valuable and important papers before the association, coupling with them the name of Dr. Letheby, of whom he spoke as being very different from the chemists they generally came in contact with. Dr. Letheby did not content himself in measuring by grains or calculating by atoms, and dealing in minute equivalents such as were known in the laboratory, but which were never found in actual practice. On the contrary, besides being a very eminent and highly instructed man, Dr. Letheby was a man of the world; he understood all the commercial and monetary difficulties with which the subject of gas supply was necessarily involved, and when he attended the meetings of that association, he instructed the members not as a mere theorist, but as a thoroughly practical teacher. He (the chairman) had never met with any man who combined so completely and so happily the man of the world and the man of science as their esteemed friend, and he congratulated the association on having again been favoured with the results of his profound research and enlarged experience. (Cheers.)

Dr. LETHEBY acknowledged the compliment paid to him, and said he felt it to be a special privilege, as one whose pursuits had been principally directed to what might be called abstract or abstruse questions of science, to have his name associated with the names of gentlemen whose papers, read before the association, had been of so practically valuable a character.

Mr. ATKINSON proposed "The officers of the past year," to which Mr. EASON responded.

Mr. GODDARD (vice-president) proposed the health of the ex-president.

The CHAIRMAN responded, and again referred to the importance of the association and his astonishment and gratification at the progress it had made, concluding with the expression of his earnest hope that it would enjoy a long course of prosperity and usefulness.

Mr. H. P. STEPHENSON proposed the healths of the new president and vice-president, to which Mr. GODDARD responded.

The CHAIRMAN proposed the health of the honorary secretary, and paid a high tribute to the zeal, ability, and courtesy displayed by him in the fulfilment of his duties, which had been so eminently conducive to the progress of the association. (Cheers.)

Mr. BLACKBURN responded to the toast. He said the service which it had been his good fortune to be able to render the association had been to him a source of real pleasure, and he rejoiced to witness its growing prosperity.

The CHAIRMAN then bade the members farewell in his official capacity, and the company broke up about ten o'clock.

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THURSDAY, JUNE 13.

This morning a party of from 40 to 50 members of the association availed themselves of the invitation of the president to visit the gas company's stations at East Croft, Poplar, Radford, and Basford, and also the water company's pumping-stations at Trent, Park, and Basford. The picturesque positions, the machinery, and the excellent arrangements at the several stations, called forth the admiration of the members, and the attention paid by Mr. Loam and the officers of the gas company, contributed very much to the enjoyment of the day, which was fully appreciated. The company also visited the magnificent park and gardens at Wollaton Hall, the seat of Lord Middleton. Other members of the association formed themselves into parties, and visited a number of the lace-works and other places of interest in the neighbourhood. Thus the very pleasant visit of the association to Nottingham was brought to a conclusion, leaving in the minds of all the members a most agreeable recollection of the urbanity, kindness, and cordiality of the president and those gentlemen who catered for their comfort, interest, and amusement.

London: Printed by WILLIAM BOUGHTON KING (at the office of Clayton and Co., 17, Bouverie Street, Fleet Street); and published by him at No. 11, Bolt Court, Fleet Street, in the City of London.—Tuesday, July 9, 1867.